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DEPARTMENT OF MINES
HON. MARTIN BURRELL, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY
WILLIAM MCINNES, DIRECTING GEOLOGIST.

MEMOIR 111

No. 91, GEOLOGICAL SERIES

The Silurian Geology and Faunas of Ontario Peninsula, and Manitoulin and Adjacent Islands

BY

M. Y. Williams

OTTAWA
J. DE LABROQUERIE TACHÉ
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1919

No. 1703

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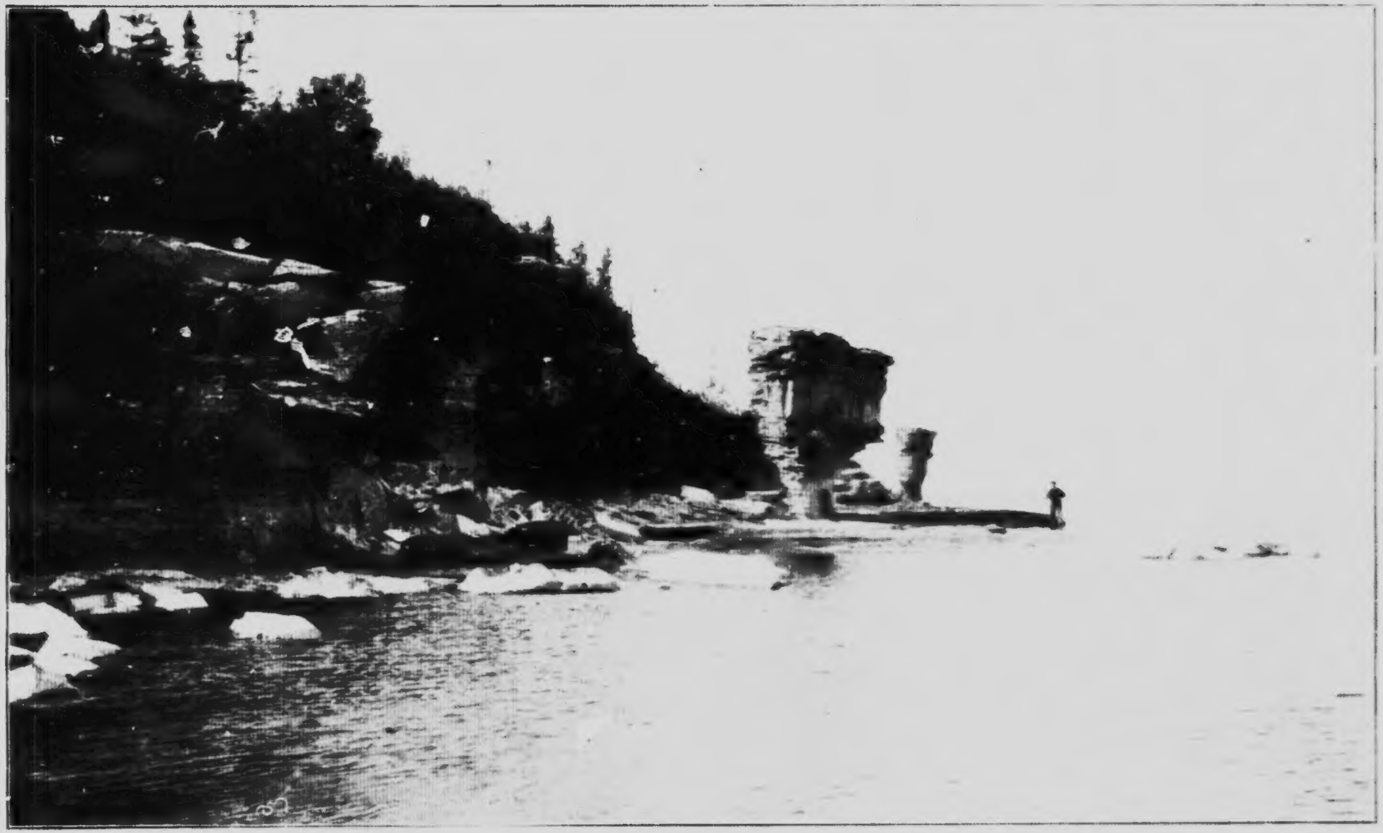

Flower pots, Flowerpot island, Georgian bay. The capping rock of the Flowerpots is Guelph, the pedistles, Niagara dolomite. (Pages 62 and 74.)

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Hon. Martin Burrell, Minister; R. G. McConnell, Deputy Minister

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CONTENTS.

CHAPTER I.

	PAGE
Introduction	1
Purpose and character of report	1
Acknowledgments	[illegible]
Previous work	2
Bibliography	4

CHAPTER II.

General character and geology of southwestern Ontario	8
Industries	8
Topography	8
General geology	9
Rock structure	11

CHAPTER III.

Summary and conclusions	15
General geology	15
Economic geology	16

CHAPTER IV.

The Silurian system	17
Table showing boundaries and subdivisions	17
General statement of extent of Silurian system	17
Lower boundary of Silurian system	17
Upper boundary of Silurian system	18

CHAPTER V.

Description of formations	23
The Medina-Cataract formation	23
Explanation of name	23
General description	23
Whirlpool sandstone member	25
Extent and characteristics	25
Origin	26
Table of distribution of fauna	28
Manitoulin member	28
General description	28
Microscopic characters	29
Fossils	29
Origin	29
Table of distribution of fauna	30
Cabot Head shale member	32
General description	32
Detailed description and sections	32
Table of distribution of fauna	35

PAGE.

        - Dyer Bay dolomite lentille 35
            - Description 35
            - Table of distribution of fauna 37
        - St. Edmund dolomite lentille 37
            - Description 37
            - Microscopic characters 38
            - Table of distribution of fauna 38
        - Origin of Cabot Head member 38
    - Grimsby sandstone member 39
        - Characteristics and distribution 39
        - Microscopic characters 40
        - Origin 40
        - Table of distribution of fauna 40
    - Thorold sandstone member 41
        - Characteristics and distribution 41
        - Table of distribution of fauna 41
        - Microscopic characters 41
        - Underground extension 41
        - Origin 42
    - Correlation and age of the Medina-Cataract formation 42
- Clinton formation 46
    - Definition and general description 46
    - Furnaceville shale member 47
        - Description 47
        - Table of distribution of fauna 48
    - Reynales dolomite member 48
        - Description 48
        - Guide fossils 48
        - Table of distribution of fauna 49
    - Williamson shale member 49
        - Description 49
    - Irondequoit dolomite member 50
        - Description 50
        - Table of distribution of fauna 51
    - Correlation of Clinton members 52
- Niagara group 52
    - Definition and use of terms 52
    - Rochester shale formation 53
        - Description 53
        - Table of distribution of fauna 54
    - Lockport dolomite formation 57
        - General description 57
        - DeCew waterlime member 58
        - Gasport dolomite member 59
        - Undivided Lockport dolomite 60
        - Beds containing chert 60
        - Beds containing *Pentamerus oblongus* 61
        - Fossil Hill coral horizon 61
        - The "Barton Beds" 61
        - Lockport dolomite not differentiated 62
        - Eramosa beds (member) 62

PAGE.
Table of distribution of fauna 64
Correlation of Niagara group 69
Niagara sedimentation 70
Guelph formation 70
Description, extent, and sections 70
Correlation 75
Guelph sedimentation 76
Table of distribution of fauna 77
Revised list of species 80
Cayugan group 82
General description 82
Salina formation 82
Description 82
Camillus shale member 83
Description 83
Origin 84
Bertie waterlime formation 84
Description 84
Fauna 86
Origin 86
Akron (dolomite) formation 87
Description 87
Fauna 89
Bass Island series 89
Definition and general description 89
Occurrences 90
Correlation of Bertie and Akron formations with Bass Island series 93
General correlation of Cayugan group 94
Cayugan history 94

CHAPTER VI.

Economic geology 96
Introduction 96
Building stone 96
Road metal and crushed stone 99
Cement 100
DeCew waterlime 100
Bertie waterlime 100
Portland cement 101
Dolomite for flux 101
Manufacture of chemicals 101
Dolomite for lime manufacture 101
Shale for brick and tile manufacture 102
Zinc blende 102
Gypsum 103
Salt 105
Petroleum 108
Gas 109
Rock analyses 110

CHAPTER VII.

PAGE.
Palæontology: description of new species and palæontological notes.............. 117
Medina-Cataract formation.. 117
Rochester formation.. 124
Lockport formation... 124
Guelph formation... 124
Appendix I. New species of brachiopod, by A. F. Foerste...................... 126
Appendix II. New species of crinoid, by Frank Springer...................... 127
Appendix III. New species of coral, by G. H. Chadwick....................... 128

Index 197

Illustrations.

Map 1715. Ontario peninsula, and Manitoulin and adjacent islands..........In pocket.
1714. Niagara peninsula, Ontario.................................... "
Plate I. Flower pots, Flowerpot island, Georgian bay. The capping rock of the Flowerpots is Guelph, the pedistles, Niagara dolomite..........Frontispiece.
II to VIII. Medina–Cataract fossils.................................... 131
IX and X. Clinton fossils... 145
XI to XIII. Rochester fossils... 149
XIV to XXI. Lockport fossils.. 155
XXII to XXVI. Guelph fossils... 171
XXVII. Guelph and Cayugan fossils.. 181
XXVIII. A. Lockport and Guelph dolomite, below car barn, Gorge route, Niagara falls, N.Y.. 182
B. Medina sandstone and shale, New York Central and Hudson River railway above Lewiston, New York.................... 182
XXIX. A. Clinton dolomite, Rochester shale and lower part of Lockport dolomite, at Grimsby.................................... 183
B. Cabot Head shale, at falls on Twentymile creek, south of Jordan.. 183
XXX. DeCew waterlime and the Gasport and overlying Lockport dolomite, Niagara gorge, New York.................................. 184
B. Upper Cabot Head shale showing current channel, Niagara gorge, New York... 184
XXXI. A. Dyer Bay dolomite and underlying red Cabot Head shale, at a locality 3 miles west of Cabot Head........................ 185
B. Quarry in Manitoulin dolomite, Owen Sound................. 185
XXXII. A. Gorge of Grand river, in Guelph dolomite near Elora.......... 186
B. Niagara escarpment. Cliffs of Lockport dolomite near Kolapore, Grey county... 186
XXXIII. A. Eramosa beds and base of Guelph dolomite, near Guelph...... 187
B. Upper Lockport and Lower Guelph dolomite, Half-Way Rock, north end Bruce peninsula............................. 187
XXXIV A. Shelburne post-office, built of local Lockport dolomite......... 188
B. Larger Flower pot, Flowerpot island, Georgian bay............ 188

PAGE.
Figure 1. Diagram showing the distribution of Silurian rocks in North America... 10
2. Diagram illustrating Silurian sedimentation in Ontario........ 17
3. Diagram showing sections along the Niagara escarpment of Ontario peninsula and Manitoulin island.......... 2
4. Characteristic geological sections in Ontario peninsula...... 2
5. Diagram showing formations near Detroit river...... 89
6. *Eucheirocrinus ontario* n. sp. Diagrammatic view....... 127

The Silurian Geology and Faunas of Ontario Peninsula, and Manitoulin and Adjacent Islands.

CHAPTER I.

INTRODUCTION.

PURPOSE AND CHARACTER OF REPORT.

The "Geology of Canada," by Sir Wm. Logan, published by the Geological Survey of Canada in 1863, includes the only comprehensive account so far published of the Silurian system of southwestern Ontario. This report has long been out of print and so is inaccessible except in the better equipped scientific libraries. Since 1863, many advances have been made in the science of geology, and it is consequently desirable that such fundamental knowledge as that relating to the Silurian rocks of the oldest settled parts of Ontario should be thoroughly revised and brought up to date. Not only is it a part of broad and enlightened education to have a clear knowledge of natural surroundings, but the proper development of our mineral resources and even our agriculture depends upon a clear understanding of geological facts. That no metal mines occur in the area described is true, but the production of non-metallic products such as lime, building stone, salt, gypsum, natural gas, etc., is and has been of the greatest importance in the development of the Ontario peninsula which is one of the most thickly settled parts of Canada.

Taken in conjunction with the recent memoir of this department on the " Devonian of southwestern Ontario ", by Clinton R. Stauffer, the present memoir completes the general description and mapping of the geology of southern Ontario as far east as the areas underlain by rocks belonging to the Ordovician system.

As described in the summary reports, the field work upon which this report is based was done during the summers of 1912 to 1916 inclusive. The whole field, including the most inaccessible parts of Manitoulin and adjacent islands and Bruce peninsula, was covered by the author or his assistants; hundreds of miles of formation boundary were followed and surveyed; numerous geological sections were studied and measured; zonal and formational collections of fossils were made, including thousands of individuals, and representing the various geological units throughout their range in southwestern Ontario; economic deposits were studied; and special trips were made to important areas in New York, Michigan, Wisconsin, and Illinois for the purpose of comparing geological occurrences in Ontario with those of the adjacent well-known regions.

ACKNOWLEDGMENTS.

Special acknowledgments are due Professor Charles Schuchert of Yale university, who spent two weeks with the author in the field during the preliminary work of 1912, and one week in 1913. His contributions to the knowledge of the Medina-Cataract problem are acknowledged elsewhere. Professor Schuchert has also kindly criticized this memoir in regard to its more important palæontological and stratigraphical conclusions.

Professor George H. Chadwick of the university of Rochester, guided the author in his studies of the Cayugan formations in western New York state and has assisted materially in solving the Cayugan problems in the Niagara peninsula. His kindness in allowing the author access to his unpublished manuscript on "The stratigraphy of the New York Clinton" has made it possible to bring the Clinton nomenclature of this memoir into harmony with the latest interpretation for New York state. His criticism of this memoir has been most helpful and constructive.

Doctors E. O. Ulrich and R. S. Bassler have kindly identified *bryozoa* and *leperditia* sent them by the author.

The assistance and kindness shown the author by managers of companies and others in the regions visited, have been acknowledged in the annual summary reports, where the names of student assistants are also mentioned. Special recognition, however, is due George S. Hume who assisted the author for two successive years and took charge of the mapping of the Niagara escarpment from Wiarton to Niaraga Falls.

The author has been in frequent consultation with E. M. Kindle, palæontologist of the Geological Survey, Canada, during the office and laboratory work required in the preparation of this memoir, and in 1913 Dr. Kindle accompanied him on a reconnaissance trip over the most important sections along the Niagara escarpment between Clinton, New York, and Collingwood, Ontario. His criticism, advice, and assistance are gratefully acknowledged.

The fossil material studied by the author includes, besides his own and his assistants' collections, collections made by E. M. Kindle in preparation of the Niagara Folio, the collections made by J. Stansfield and H. V. Ellsworth, in 1912, and the old collections in the possession of this Survey.

PREVIOUS WORK.

Many eminent geologists have published descriptions of various phases of the geology of southwestern Ontario, the following being a brief review of the more important contributions to date. For publications not mentioned the reader is referred to the selected list given under Bibliography.

The Rogers brothers of Pennsylvania contest with Alexander Murray, assistant to Sir William Logan, the honour of publishing the first description of the Silurian formations of Ontario. In the report of 1843, the first to be issued by the newly organized Geological Survey of Canada, Murray traced the formations of western New York into western Ontario, then western Upper Canada, giving a general description and outline of their areal extent. A similar report was published the same year by

Rogers and Rogers in the "Transactions of the American Philosophical Society". It devolved upon the Canadian Survey, however, to complete the task of surveying the Ontario region. Murray, in spite of much other work, returned from time to time to his original task, describing the east side of Bruce peninsula and the Manitoulin islands in the report of 1847-48, the west side of Ontario peninsula from the north end of Bruce peninsula to Amherstburg, in 1848-49, and rounding out the field work by completing the mapping of the Niagara escarpment as described in the report of 1850–51. The geological map of western Ontario first appeared as part of a map of the region from the west end of lake Ontario to lake Michigan, in the Canadian Institute proceedings in 1854, accompanying an article by Sir William Logan "On the physical structure of the western district of upper Canada". Meanwhile the solving of geological problems went on harmoniously in Canada and New York state, the heads of the two Surveys, Sir William Logan and James Hall, respectively, being on the best of terms. In 1852 Hall published the "Palæontology of New York", vol. II, which greatly facilitated working out the palæontology and stratigraphy of Ontario. In 1863, Logan published his "Geology of Canada", in reality as stated, a summary of the work of the Canadian Geological Survey from the beginning. With maps, illustrations of fossils, and descriptions of formations, this is still the only work that claims to be a geology of Canada and its excellence is recognized by all authorities. Between the years 1863 and 1910 many publications dealing directly or indirectly with the Silurian system of Ontario appeared in government reports of Canada and the United States and in various periodicals. T. Sterry Hunt, chemist to the Canadian Geological Survey, published many observations on the geology of Ontario, including notes on the salt and gypsum deposits; Robert Bell described the geology of the Manitoulin islands; Alexander Winchell wrote on the "Geology of petroleum in Canada west"; H. A. Nicholson wrote on the "Palæontology of Ontario"; Hall further described the Niagara and Lower Helderberg formations of United States and Canada; Whiteaves described the Guelph fauna of Ontario; and Clarke and Ruedemann described the Guelph fauna of New York. These and other publications of like character added information but made no basic changes in the geology as laid down by Logan in 1863.

In 1910 the "Monroe formation", by Grab[illegible] and Sherzer, appeared as a report of the Geological and Biological Survey of Michigan. This vigorously attacked the accepted interpretation of the age of those formations of western Ontario which had formerly been considered the oldest Devonian formations of the region. As a result an awakened interest was centred on western Ontario, culminating for the Devonian system in the "Report on the Devonian of southwestern Ontario", by C. R. Stauffer, and for the Silurian system in papers by Charles Schuchert, Grabau, and the writer, and the present memoir. The meeting of the Twelfth International Geological Congress in Toronto in 1913 necessitated much geological housecleaning, and when Professor Charles Schuchert accompanied the writer over the Silurian rocks of the Georgian Bay region and Manitoulin island and later went with Dr. W. A. Parks over the Silurian sections of Credit Forks, Hamilton, and Grimsby, he saw clearly that new correlations for the so-called Clinton and Medina horizons must be made. Schuchert's work has been followed up by the writer, along with a revision of the whole Silurian system in southwestern Ontario.

The economic side of the Silurian geology of Ontario has been dealt with in recent reports as follows: "Building and ornamental stones", W. A. Parks, 1912; "Gypsum in Canada", L. H. Cole, 1913; "Salt deposits of Canada", L. H. Cole, 1915; "Oil and gas in Ontario and Quebec", W. Malcolm, 1915; "Records of wells drilled for oil and gas in Ontario", Cyril W. Knight, 1915; "Petroleum and natural gas resources of Canada", F. G. Clapp, 1914-15. (See Bibliography for fuller references.)

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CHAPTER II.

GENERAL CHARACTER AND GEOLOGY OF SOUTHWESTERN ONTARIO.

INDUSTRIES.

That part of southwestern Ontario underlain by rocks of Silurian age, includes some of the richest and most thickly settled agricultural districts in Canada. With splendid transportation facilities, manufacturing industries have developed rapidly in centres such as Welland, Brantford, Guelph, Kitchener, Stratford, and a host of smaller places. The shallow soil near the edge of the Niagara escarpment is largely covered by wood lots or is used for pasture. The rocky land on Bruce peninsula and Manitoulin island, now that the best of the timber has been harvested, is utilized for farming and grazing in the more suitable areas, and elsewhere is left for the growth of hardwood. Excellent farm land occurs in parts of Bruce peninsula, particularly west of Lyon head, and much good farm land is worked on Manitoulin island, areas near Manitowaning, Little Current, and Mindemoya, at the head of South bay, Gore bay, and on Barrie island, being settled by prosperous farming communities.

Throughout the Georgian Bay and Lake Huron regions, fishing is an important industry and the abundance of game fish, combined with the natural picturesqueness and variety of scenery, are strong attractions for summer tourists.

The mineral products obtained from the Silurian rocks consist of commonplace non-metallics, such as road metal, building stone, quicklime, salt, gypsum, gas, and some oil. These products, however, are of great potential value when their proximity to the centres of population is taken into account. The splendidly ordered gypsum mine at Caledonia formerly owned by the Alabastine Company and now owned by the Ontario Gypsum Company, is a revelation to the average man, who disconnects mining entirely with this part of Ontario. The salt wells of the Kincardine, Goderich, and Sarnia regions practically control the Canadian market for salt and immense reserves are as yet untouched. The salt production for 1917 is valued at $1,095,866. The gas produced in Ontario in 1917 was valued at $3,182,154 and this was mostly derived from the Silurian formations.

TOPOGRAPHY.

The topography of the Silurian areas is generally of low relief, the only feature of important dimensions being the Niagara escarpment which forms a step upward to the west and south from the lowlying Ordovician plains to the east and north. This sinuous escarpment is the outcropping edge of the resistant Niagara (Lockport) dolomite, into which the agents of erosion have eaten. On the mainland of Ontario, the eastern extension of the Silurian system is practically terminated by the Niagara escarpment, but the Manitoulin dolomite and the Whirlpool sandstone, at the base of the Cataract formation, extend in places considerable distances to the east or north from beneath the Niagara dolomite, forming at their eroded edges one or more additional, but insignificant escarpment . On Manitoulin island the escarpment formed by the Manitoulin dolomite is comparatively conspicuous. To the west and south of the Niagara escarpment, the land surface in general tends to slope away to the southwest down the general dip of the formations. Numerous modifications occur, however, due to accumulations of glacial and outwash materials and to glacial and other erosion of the hard rock surfaces. Examples of eroded rock surfaces are common along the Niagara escarpment, on Bruce peninsula, and on Manitoulin and the adjacent islands. On Bruce peninsula and the islands to the north, the solid dolomite has been sculptured into innumerable mounds, hills, and valleys, the latter containing more or less gravel clay, and soil. Excepting the southern half of Niagara peninsula which is mostly very level, the areas underlain by Silurian rocks are generally undulatory, the more prominent hills being due for the most part, as at Durham, to the presence of glacial moraines, and the more pronounced valleys being due to river channels, such as those of the Saugeen and the Grand. Where the drift is deep, the outcrops of rock are practically confined to the river valleys.

The maximum recorded elevation for the region described is 1,700 feet A. M. T. at Dundalk. The maximum for the Manitoulin island is 1,020 feet A. M. T. southeast of lake Manitou. The minimum elevation for any part of the country obviously depends upon the elevation of the great lake into which its streams empty.

GENERAL GEOLOGY.

Southwestern Ontario lies in the northern, central part of the Palæozoic sedimentary area which occupies the basin of the Great Lakes, exclusive of lake Superior, extends from the Appalachian mountains on the east to Kansas and Nebraska on the west, and includes the drainage basin of the Mississippi river as far south as Oklahoma, northern Tennessee, and central Alabama. Of this vast area, the rocks of Silurian age outcrop over only a small part. The other systems of Palæozoic rocks represented in Ontario are the Cambrian, Ordovician, and Devonian. The Carboniferous system with its coal beds is found nowhere within the province, but outcrops to the west in Michigan and to the south in Ohio. The Palæozoic formations rest upon an uneven floor of Pre-Cambrian, igneous and metamorphic rocks, which consist of granites, diabases, gabbros, gneisses, schists, quartzites, crystalline limestones, etc. This basal complex outcrops to the north as the Canadian Pre-Cambrian shield. Corresponding to the gentle southerly dip of the Pre-Cambrian floor, the sedimentary strata in southwestern Ontario are inclined in general to the southwest with an average dip of about 20 feet a mile. East of lake St. Clair, however, a basin structure occurs and there is in consequence an easterly dip in the region south of lake St. Clair and east of Detroit river. The maximum thickness of the Palæozoic strata, as taken from a well record in the basin just mentioned, is 3,635 feet, of which 35 feet is basal arkose or conglomerate, 1,625 feet includes the Ordovician and any lower Palæozoic strata that may be present, 1,725 feet is the thickness of the Silurian system, and 280 feet is the thickness of the Devonian formations present.

On the east and north the Silurian rocks are bounded approximately by the Niagara escarpment, which is a well-defined and conspicuous feature of the landscape from central New York to Niagara Falls, and thence through Hamilton, to the vicinity of Collingwood, along the south and

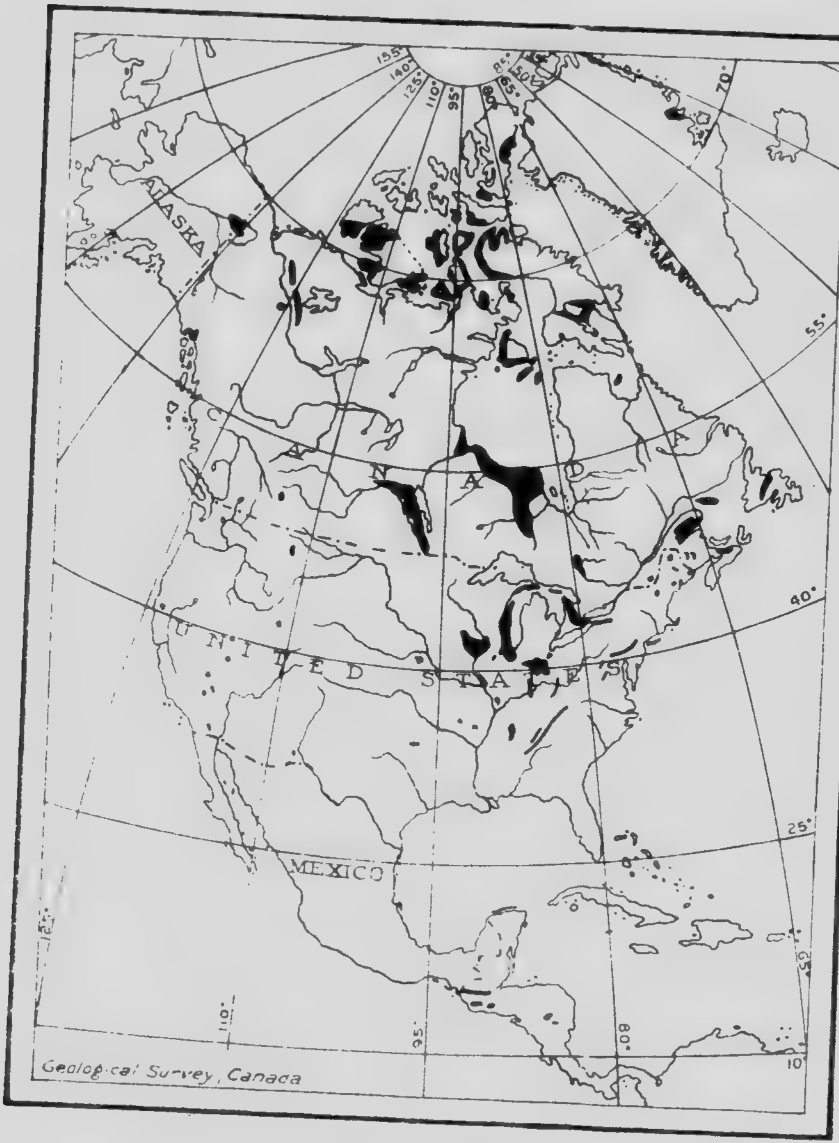

Figure 1. Diagram showing, in black, the distribution of Silurian rocks in North America.

western shores of Georgian bay, through a chain of islands to Manitoulin island, throughout the length of Manitoulin, Cockburn, and Drummond islands to the northern peninsula of Michigan. The islands separating Georgian bay and the North channel from lake Huron are so continuous and so closely connected by reefs that the break here is more apparent than real.

Although Silurian formations underlie the whole area from the Niagara escarpment to the limits of the province on the south and west, the area not overlain by Devonian strata is much more restricted, as may be seen from the map, and the actual exposures of rock occupy only a small part of this area.

The sandstones, shales, and interbedded dolomites, comprising the lower part of the Silurian system (the Medina-Cataract, the Clinton, and Rochester subdivisions) outcrop along the front of the Niagara escarpment, or in case of the harder subdivisions, occur by themselves to the east or north as more or less localized escarpments. The overlying, heavy-bedded dolomite of Niagara age (Lockport) forms the practically continuous white cliffs of the Niagara escarpment.

West and south of the Niagara escarpment, the Lockport dolomite outcrops over wide areas of country, particularly on Bruce peninsula and Manitoulin and the neighbouring islands, where large areas of barren rock are exposed. The Guelph dolomite overlies the Niagara (Lockport) dolomite and outcrops over considerable areas to the south and west of the Niagara belt, continuing as far north as Fitzwilliam island. The waterlime, shales, and gypsum beds of the Cayugan group are rarely seen at the surface, sections occurring as indicated on the map in the valleys of Grand River, Saugeen river, and in some other stream channels. The salt beds do not outcrop at all.

In many parts of Ontario peninsula, bedrock is deeply covered by surface deposits, consisting of boulder till, and outwash materials such as clay, gravel, sand, etc. The study of this surficial geology is an extensive subject in itself and has been described in part by J. W. Goldthwait and F. B. Taylor (see Bibliography).

In areas where rock exposures are scarce owing to the thickness of the surface deposits, the land is generally good and the country is thickly populated. In consequence, rock outcrops are of great potential value as a source of raw material for building stone, road metal, lime manufacture, etc., and those discovered in the preparation of this report have been indicated on the map.

ROCK STRUCTURE.

Since Pre-Cambrian time, southwestern Ontario has not suffered in any way from violent deformation, but on the other hand the movements of the earth recorded elsewhere in faults and sharp folds have resulted in gentle structural undulations, which rarely assume a magnitude of dip of 200 feet per mile, but which are nevertheless controlling factors in the accumulation of oil and gas. The oil fields of Essex, Kent, Lambton, and Middlesex counties are located for the most part on gentle domes and anticlines, and the gas fields between Niagara and Detroit rivers, where studied, have been shown to be closely associated with inverted basin structures, although varying rock porosity in some cases is the primary controlling factor of gas as well as of oil occurrence, and in formations that do not carry water the oil and gas may be found in the basins and synclines.

A few conspicuous indications of structure have been cited in previous reports. In the "Geology of Canada", 1863, and again as restated by Malcolm[1] the Cincinnati anticline which is a decided feature in the Ohio valley, "forms a gentle curve running from the west end of lake Ontario, through Woodstock, along the Thames, and through Chatham to the southern part of Essex county. This diffuse fold is possibly composed of subordinate folds, none of which are pronounced or have limbs dipping at more than a few feet per mile." The diffuseness of this fold is well demonstrated by a detailed study made by the author of the structure at the Bothwell oil field where low minor folds are quite complex in arrangement. There are very good grounds for locating the broad anticline as above stated, but it is well to emphasize the diffuseness of its characters and not to expect a continuous, clearly defined, structural feature. It is probably a zone of low folds rather than a single well-marked anticline.

Anticlines have been located by Bell on the map of Manitoulin island, and judging from the shape of the topographic features of the land some of these at least may be as indicated. Much more detailed work is required, however, to interpret satisfactorily the comparatively gentle structure of Manitoulin island.

Two anticlines at Rockwood were described by Logan.[2] The one at the top of the Niagara (Lockport) is a well-marked structure and is further described below. The reference to a cross fold from Eden through Rockwood to Orangeville, appears to be based upon re-entrants in the supposed boundary between the Guelph and Lockport formations, re-entrants which do not exist in the revised boundary. The marked anticline in the top of the upper Lockport dolomite, which extends through Rockwood village, is very clearly defined 200 yards southwest of the road bridge crossing the Eramosa river. Here, the river cuts through the crest of the anticline which for a width of about 5 degrees to the east and west. Farther from the crest the dip is 10 to 11 degrees on the east and somewhat less on the west. Eastward as far as the river and south of the railway track, the strata dip at the rate of 4 to 5 degrees to the east, but for three-quarters of a mile north of the railway bridge, the river bed is on the crest of a low anticline which merges into the more pronounced structure south of the railway. A small syncline intervenes between this anticline and the crest of the main anticline west of Rockwood station, and eastward from the railway bridge a similar syncline occurs, succeeded eastward by a low anticline. Thus it is clear that the main anticline is flanked to the eastward by minor folds. To the west the dip is clearly shown, although undulatory, as far as a small remnant of Guelph dolomite south of the Grand Trunk railway, about 400 yards west of Rockwood station. The Eramosa beds which form the upper part of the Lockport formation intervene between the rock at the village and the Guelph remnant to the west and allowing for their thickness (40 to 50 feet) and averaging the rock dips, it is estimated that the dip to the west is about 70 feet in 1,200 feet, or at the rate of about 300 feet per mile. As the average dip of the formation to the west is about 20 to 30 feet per mile, it is clear that the anticline is well marked. The crest of the anticline extends through the Agricultural grounds, the west side of the schoolyard, and through the middle of the rock-cut on the railway about 235 yards west of the station, and crosses the road between concessions IV and V, Eramosa township, near the north side of lot 6. The axis of the anticline extends nearly northwest from Eramosa river, but curves more and more to the north in its northern exposures. To the south of Rockwood the rock is covered with a thick mantle of surface material.

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[1] Geol. Surv., Can., Mem. 81, p. 45.

[2] "Geology of Canada", 1863, pp. 330 and 343

Stauffer[1] described an anticline passing through St. Marys as follows: "Running nearly north and south through the city there is a rather pronounced anticlinal or monoclinal fold............which brings up the Silurian[2] to the east and drops the Devonian to the west. The Thames river cuts into the side of this fold so that at the dam near the Queens Street bridge the dip is upstream, while a quarter of a mile below the bridge, the dip is downstream. The excellent artesian wells which supply St. Marys with such a quantity of good water may depend on this same structure."

Folds have been mentioned at other localities, but it is difficult to prove their existence.

As may be seen from the cross section passing through Elora (see Map 1715), there evidently is a monoclinal fold to the west of that town. Such a fold is strongly suggested by comparing the altitude of the top of the Guelph outcrops at Elora and the altitude of the top of the formation derived from the depth at which Guelph dolomite was struck in a well drilled on lot 6, concession V, Pilkington township, about 5 miles west of Elora.

Undulations are clearly marked along the north end of Bruce peninsula between Cabot head and Tobermory, a clearly cut escarpment being exposed all the way and the water-level being everywhere a handy reference plane. The best marked anticline extends from the outlet of Gillies lake northwesterly to the small area of Cataract exposures on the northern shore. The easterly dip of this fold as seen on the north shore is about 110 feet in a mile, the corresponding dip at Gillies lake being much less. The dips to the west are similar. A well-marked syncline parallels the anticline on the east and includes the three conspicuous bluffs west of Cabot head, whose axes are at right angles to that of the syncline. Farther west the undulations are not so easily determined because of the lack of horizon-markers, but they are quite evident to an observer coasting along the shore. Other slight undulations may be seen along the east side of Bruce peninsula.

The gentle monoclinal structure of the Niagara peninsula is clearly illustrated by the three structural sections accompanying the special map of this region. Kindle states[3] that "Between the New York Central Railway bridge and the elevator shaft at the falls the beds dip to the south at an average rate of $28\frac{1}{2}$ feet to the mile. The rate of dip along the norther two-thirds of the gorge is somewhat less.........................

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[1] Geol. Surv., Can., Mem. 34, p. 113.

[2] Detroit River series and hence now considered Devonian.

[3] U.S. Geol. Surv., Niagara Folio No. 190, 1913, p. 14.

"A group of more than twenty wells drilled for the Tonawanda Ga Company affords complete data concerning the rate of dip. .... about Getzville...................The available facts indicate tha along an east-west belt of territory............ ..the southerly dip o the rocks is about 10 or 12 feet greater to the mile than in the contiguou territory on the north".

Getzville is 5 miles east of Tonawanda and almost due east of the comparatively steep dips indicated in the section passing through Niagar falls. At Getzville, this change of dip has caused the accumulation o an important gas pool in the Medina sandstones.

To the westward the monoclinal structure merges into the broa diffuse east-west fold of the Cincinnati anticline which is generally considered as having its axis along the Dundas valley[1].

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[1] Geol. Surv., Can., vol. V, pt. Q., pl. V, pp. 1-94.

CHAPTER III.

SUMMARY AND CONCLUSIONS.

GENERAL GEOLOGY.

The Silurian system is bounded below, in Ontario peninsula, by the red Queenston shale and on Manitoulin island by the Richmond shales and limestones. These underlying formations belong to the Cincinnatian group of the Ordovician system and are only facies of the same sedimentation. Above, the Silurian is bounded by different Devonian formations, the Oriskany sandstone and Onondaga limestone in the Niagara peninsula, and the Sylvania sandstone and Detroit River series in the Lake Huron, Lake St. Clair, and Detroit River regions. In intermediate areas the facts are less definitely known. The total thickness of Silurian strata at lake St. Clair is from 1,725 to 1,750 feet.

The Silurian system falls lithologically into three subdivisions, a lower one typically marked by an alternation of clastic and calcareous sediments, the result of changing conditions of the land in respect to the sea; a middle group of massive dolomites, suggestive of widespread seas of moderate depth; and an upper division of saline sediments containing lenses of salt and gypsum and impure, clastic dolomites. The saline deposits are probably those of shallow, interior basin, water bodies, which received great quantities of detrital material from the surrounding areas where older formations elevated above sea-level were being actively eroded. The last phase of Silurian sedimentation represented a brief return to normal marine conditions, which were terminated by the uplift preceding Devonian time.

The oldest Silurian division includes: (1) the sandstones and shales of the Niagara peninsula (Medina) and the contemporaneous dolomites, shales, and shaly dolomites (Cataract) of the Georgian Bay region; (2) the limestones of the Clinton formation which scarcely extend in outcrop beyond the Niagara peninsula; and (3) the Rochester shale which thins out a few miles north of Hamilton.

The middle division includes the widespread Niagara dolomite, suitably known as Lockport dolomite, and the Guelph dolomite which is indicative of a shallowing sea, approaching interior basin conditions.

The upper division of the Silurian includes the Cayugan group, with its Salina shales, gypsum and salt, these being the extension of the Camillus shale of New York, and the overlying Bertie waterlime and Akron dolomite, which merge laterally into the lower Monroe dolomites of the Lake Huron-Detroit River region.

The best marked disconformities or breaks in sedimentation occur: (1) at the base of the Silurian where the Whirlpool sandstone and Manitoulin dolomite overlap the Queenston shale and marine Richmond formation; (2) at the base of the Lockport dolomite which successively overlaps from the north the Cataract, the Clinton, and the Rochester formations; (3) at the base of the Salina which overlies what appears to be an erosion surface at the top of the Guelph formation; and (4) at the top of the Silurian as represented by the Bass Island series in the west and the Akron dolomite in the east. The contact between the Akron dolomite and the overlying Oriskany sandstone and Onondaga limestone is clear characterized by an erosion unconformity, and the corresponding conta in the west between the Bass Island series and the Sylvania sandstone probably similar, but it is known in Ontario only from well records.

ECONOMIC GEOLOGY.

All the Silurian calcareous sediments in Ontario are highly magnesia and are classed as dolomites. This implies that where sufficiently fr from impurities such as clay and silica the Silurian dolomites may be bur for lime manufacture and are especially suitable for hydrated lime; b they are entirely unsuitable for the manufacture of Portland cemen Guelph dolomite at Guelph, Fergus, and elsewhere is extensively used f the manufacture of quicklime. The Manitoulin, Clinton, Lockpor Bertie, and Akron dolomites are generally suitable for quicklime man facture and have been used to some extent. Natural rock cement wa formerly made from the argillaceous dolomites or "waterlimes" at th base of the Lockport dolomite at Thorold, Mt. Albion, and elsewher and from the Bertie "waterlime" of Bertie township. This industry now abandoned, because of the inferiority of natural rock cement to th high grade Portland cement now used in construction work.

The best known Silurian building stones are obtained from th Whirlpool sandstone, the Credit Valley "Brown stone" being very favour ably known, and from the Lockport and Guelph dolomites. The grea extent of the exposures of the last two named formations makes the easily available for many cities and towns, and it is only because ston has given place to cheaper building materials that this fine natural resourc has been very little developed. The Manitoulin or lower Cataract dolomit of Manitoulin island is in many cases suitable for building stone, althoug here as farther south it is commonly too thin-bedded and shaly.

The best Silurian rock for road metal includes the upper and harde beds of the Lockport dolomite, the denser and harder beds of the Guelp dolomite, and much of the Akron dolomite (including probably a part o the Bertie beds) outcropping near Cayuga, Dunnville, and elsewhere i the Niagara peninsula.

Large gypsum deposits occur in the Salina formation along the Gran river between Paris and Cayuga. These are at present mined at Caledoni and York.

Extensive and as yet only partly developed beds of salt occur in th Salina formation over a large area extending east from lakes Huron an St. Clair, between Kincardine and Port Lambton, as far as Brussels, London, and Dutton. Another area is situated in the vicinity of Windsor. These areas are the centre of the salt industry in Canada.

Much gas is derived from the Medina sandstone (the Whirlpool an overlying beds) in Niagara peninsula and as far west as Delhi. Th Clinton limestone furnishes gas in the Onondaga, Caledonia, Cayuga, an Port Colborne fields. The Guelph dolomite is gas-bearing in easter Essex county.

Some oil is obtained from the Whirlpool sandstone near Brantford (this is variously reported from the Whirlpool and the underlying Queenston) and the Guelph and Salina furnish the oil of the Tilbury field of Kent and Essex counties.

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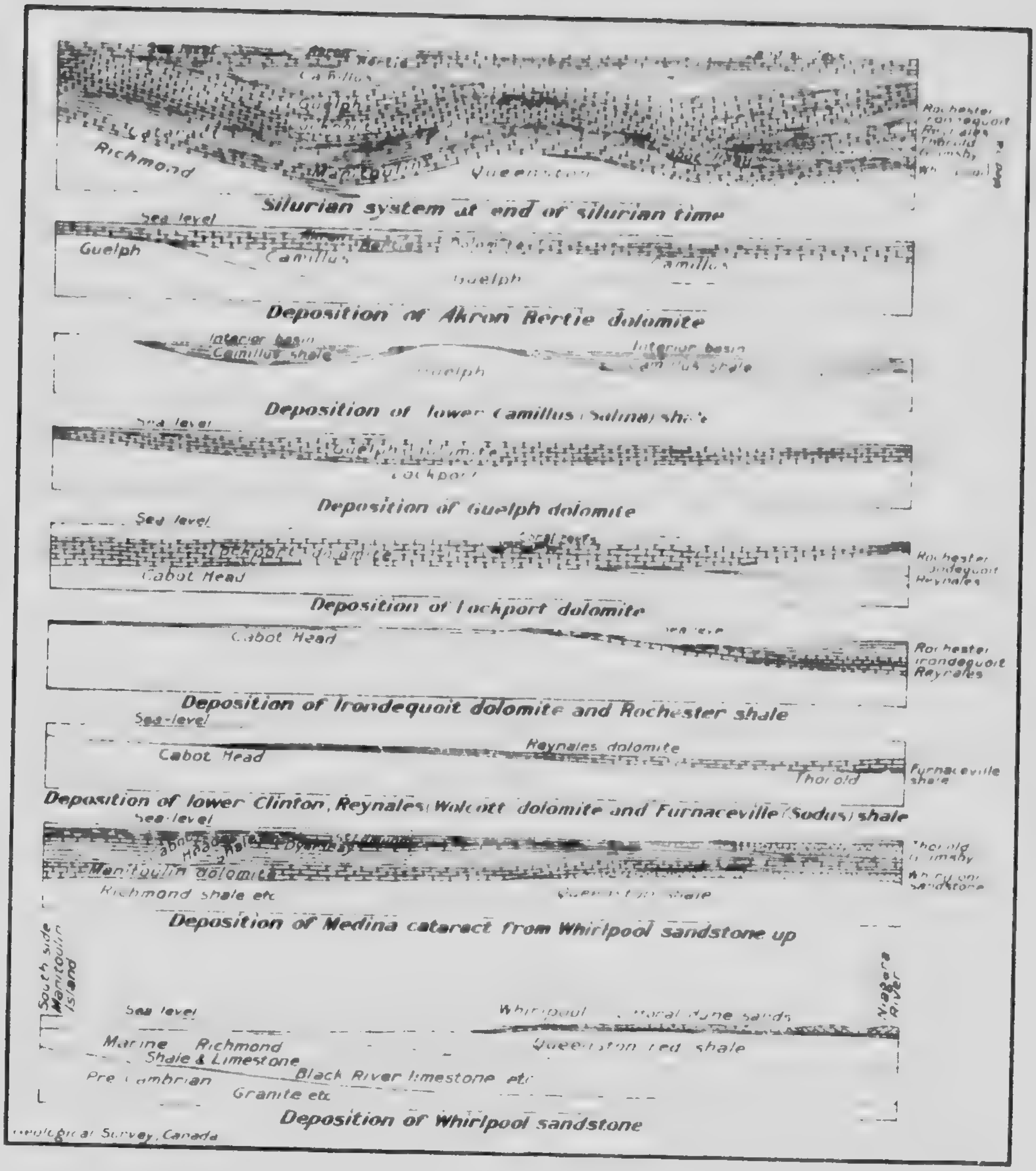

Figure 2. Diagrams illustrating Silurian sedimentation in Ontario

To accompany Memoir by M.Y. Williams

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CHAPTER IV.

THE SILURIAN SYSTEM.

GENERAL STATEMENT OF EXTENT.

The Silurian system includes the sediments deposited between the emergence of the land from the sea which closed the Ordovician period, and the like emergence which brought the Silurian period to a close. According to the author's interpretation for Ontario, the Silurian formations would be those lying between the sediments of Richmond age (including Queenston shale) below and the Oriskany sandstone, Onondaga limestone, or Sylvania sandstone, whichever happened to be the local overlying formation of the Devonian system, above.

As geologists are not unanimous regarding either the lower or the upper Silurian limits some explanation of the author's conclusions is necessary. Let us first consider the lower Silurian boundary.

LOWER BOUNDARY.

Until recent years, geologists have unanimously placed the Ordovician-Silurian boundary at the top of the well-recognized marine Richmond formation. This conclusion was based on a mass of paleontological evidence and was in accord with stratigraphic evidence as well. Geologists, following the terminology of New York state, also unanimously accepted the base of the "Red Medina," now known as Queenston shale, as the lower boundary of the Silurian. This decision was based on the assumption that the Queenston shale overlay and was younger than the Richmond formation, and was in continuous deposition with the overlying "Medina" used in the restricted sense. As no fossils were known in the Queenston shale, paleontological evidence was entirely lacking. In 1909[1] Grabau showed that the Queenston shale is merely a delta phase of Richmond sedimentation, and hence is of the same age as the Richmond. The majority of geologists at once accepted the top of the Queenston shale as the top of the Ordovician system in accordance with the long recognized treatment of the Richmond marine sediments. A few geologists, however, continued to interpret the Ordovician-Silurian boundary as being at the base of the Queenston and so placed it at the base of the typical Richmond formation. For this view of the case the reader is referred to the writings of E. O. Ulrich.[2] So far as Ontario is concerned a stratigraphic break between the top of the Queenston shale and the overlying Whirlpool sandstone is indicated not only by a decided change in sedimentation but also by mud cracks in the Queenston filled with sand from the Whirlpool beds. In the Georgian Bay region, however, where the Manitoulin dolomite overlies shale of the marine Richmond formation, there is a far more decided break in both sedimentation and fauna. Not a single species listed by

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[1] Science, new ser., vol. XXIX, p. 356.

[2] "The Ordovician-Silurian boundary". Twelfth Inter. Geol. Cong., 1913, C. R., pp. 593-667.

Foerste from the Richmond of this region is known in the Manito dolomite, and the genera that cross over are few in number and of l ranging characters. These facts have caused the author to adopt more widely accepted view of stratigraphers.

UPPER BOUNDARY.

The problem of the upper contact of the Silurian system in the Detr river-Lake Huron region is even more complicated and obscure th is that of the lower contact just described. In the Niagara penins and vicinity the Oriskany sandstone, or in its absence the overlying On daga limestone (both of undoubted Devonian age) disconformably ove the Akron dolomite of undoubted Silurian age and the boundary is t definitely located. From the vicinity of Woodstock westward, howev the Monroe formation of Grabau intervenes between the easily-recogni Silurian and Devonian formations, and Grabau has placed all of t series in the Silurian system. Unfortunately for the solution of the pr lem, outcrops of Monroe strata are scarce, few good sections are know and much has to be inferred from samples taken from drill holes.

The accompanying table gives Grabau's interpretation of the Mon formation. This succession was determined from the studies made the Michigan geologists during the sinking of a salt shaft near Detr and from natural sections and bore-holes in Ohio and Michigan. N withstanding the criticisms of this interpretation of the sequence of formations by the Rev. Thomas Nattress,[1] there is good reason to beli that it is substantially correct.

	Dundee formation		
		Disconformity	
Monroe formation	C. Upper Monroe or Detroit River series	Lucas dolomite	200 f
		Amherstburg dolomite	20
		Anderdon limestone	35- 50
		Flat Rock dolomite	40-100
		Disconformity	
	B. Sylvania sandstone and dolomite		30-300
		Overlap	
	A. Lower Monroe or Bass Island series	Raisin River dolomite	200
		Put-in-Bay dolomite	100
		Tymochtee shales	90
		Greenfield dolomite	100
		Disconformity	
	Salina formation		

The lower Monroe or Bass Island series is undoubtedly Silurian a will be described under "Cayugan group." Grabau has demonstrated th the typical Sylvania sandstone of Michigan is in part of sand dune orig and hence represents continental sedimentation transgressing the Siluri land. A further discussion of the characters and age of the Sylvan

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[1] Nattress, Thomas. See Bibliography

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Boundaries and Subdivisions of the Silurian System of Southwestern Ontario.

System.	Formation.		Localities.			
			Niagara river.	Dundas.	Bruce peninsula.	Detroit river
Devonian.	Onondaga Oriskany Detroit river. Sylvania.		Onondaga limestone. Oriskany sandstone and conglomerate in lenses			Onondaga Dundee limestone Oriskany? sandstone thin lenses, age uncertain Detroit River limestone and dolomite, four members Sylvania sandstone
Silurian.	Cayugan group	Akron.	Akron dolomite.			Bass Island Raisin River dolomite Put-in-Bay dolomite Tymochtee shale Greenfield dolomite
		Bertie.	Bertie waterlime.			
		Salina	Camillus shale including gypsum.	Present land surface.	Present land surface.	Camillus shale including salt an gypsum
	Guelph.		Guelph dolomite.	Guelph dolomite.	Guelph dolomite.	Guelph dolomite
	Niagara group.	Lockport.	Eramosa beds. Dolomite. Gasport dolomitic limestone DeCew waterlime.	Eramosa beds. Dolomite. Chert beds.	Eramosa beds. Dolomite.	Lockport dolomite
		Rochester.	Rochester shale.	Rochester shale (very thin.)		Rochester shale.
	Clinton.		Irondequoit dolomite. Williamson? shale. Reynales (Wolcott) dolomite. Furnaceville? (Sodus) shale.	Irondequoit dolomite (very thin.) Reynales (Wolcott) dolomite.		Dolomite.
	Medina-Cataract.		Thorold sandstone. Grimsby sandstone. Cabot Head shale. Manitoulin beds (shale and calcareous sandstone). Whirlpool sandstone.	Grimsby sandstone. Cabot Head shale. Manitoulin dolomite. Whirlpool sandstone.	Cabot Head shale: St. Edmund dolomite. Shale. Dyer Bay dolomite. Shale. Manitoulin dolomite.	Cabot Head shale Manitoulin dolomite.
Ordovician.	Richmond and Queenston.		Queenston shale.	Queenston shale.	Queenston shale.	Queenston shale.

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sandstone is to be found below. The controversy, however, centres about the age of the upper Monroe or Detroit River series. The palæontologic and stratigraphic evidence apparently conflict, and it is, therefore, necessary briefly to review the evidence in order to make the author's conclusions clear.

The Devonian characters of the Detroit River series are well represented by the following fossils: *Syringopora* cf *hisingeri* Billings, in the Flat Rock dolomite; *Cystiphyllum americanum* mut. *anderdonense* Grabau, *Favosites basaltica* mut. *nana* Grabau, *Conocardium monroicum* Grabau (closely related to *C. trigonale* Hall), in the Anderdon limestone; *Romingeria umbellifera* Billings, *Panenka canadensis* Whiteaves, *Conocardium monroicum* Grabau, *Proetus crassimarginatus* Hall, in the Amherstburg dolomite; and *Romingeria umbellifera* (Billings), *Conocardium monroicum* Grabau, *Panenka canadensis* Whiteaves in the Lucas dolomite. Grabau[1] says of the fauna of the Flat Rock, Anderdon, and Amherstburg beds: "Its most characteristic feature is its Devonic element. If the fauna were considered by itself, it would probably be pronounced a Schoharie or an Onondaga fauna without hesitation, though there is a considerable Siluric element. The position of this fauna beneath 200 to 250 feet of the Lucas dolomite with a Siluric fauna, forces us to consider this as Siluric." It will be seen below just how important the Siluric element in the Lucas dolomite is. Continuing, Grabau says[2] "To sum up, the stromatoporoids of this fauna are partly Siluric and partly of Devonic types. The corals are represented by nine Siluric species and thirteen species identified with or most nearly like mid-Devonic species. The brachiopods are, with two exceptions, of types otherwise known only from the mid-Devonic. The pelecypods are similarly mid-Devonic types, and so are the trilobites. The gastropods and cephalopods, on the other hand, are without exception upper Siluric types."

Of the Lucas fauna, Grabau says[3] "This is the highest fauna of the Monroe group, and it is throughout a Siluric fauna." An analysis of his summary of this fauna, however (page 221), gives the following information: Of corals there are two specific identifications, one species (*Cylindrohelium profundum*) being new and one species (*Cladopora dichotoma*) persisting from the Anderdon limestone; of seven species of brachiopods, four (*Prosserella lucasi*, *P. subtransversa*, *P. unilamellosa*, *P. planisinosa*) are found only in the upper Monroe, two (*Schuchertella interstriata* and *Spirifer modestus*) in the upper Silurian, and one (*Camarotœchia semiplicata*) in the upper Silurian and lower Devonian; of three pelecypods, two (*Panenka canadensis* and *Conocardium monroicum*) are found in the lower horizons of the upper Monroe and are of decided Devonian character, and one (*Pterinea bradti*) is a new species considered a derivative of a species of the lower Monroe (*P. lanii*); of nineteen species of gastropods listed on page 212, three (*Hormotoma subcarinata*, *H. tricarinata*, and *Pleurotrochus tricarinatus*) have their nearest relations in the upper Silurian of Gottland, six (*Eotomaria areyi*, *E. galtensis*, *Lophospira bispiralis*, *Pleurotomaria* cf *velaris*, and *Poleumita* cf *crenulata*) are Guelph, and three (*Solenospira minuta*, *S. extenuatum*, and *Holopea subconica* are Manlius, two species (*Pleuronotus subangularis*, and *Trochonema ovoides*) are closely related to

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[1] Michigan Geol. and Biol. Surv., Pub. No. 2, Geol. ser., p. 217.
[2] Ibid, p. 221
[3] Ibid, p. 221.

Devonian forms; and the remaining five species (*Acanthonema holopiform* *A. holopiformis* mut. *obsoleta*, *A. laxa*, and *A. Newberryi*) are confined the Lucas and Amherstburg beds.

In all, twenty-four genera are recognized in the Lucas dolomite. these, two are known only in the upper Monroe, and the remainder a represented as follows: six, Ordovician to Carboniferous or later; tw Ordovician to Devonian; two, Ordovician to Silurian; one, Silurian Carboniferous; two, Silurian to Devonian; four, Silurian; and one, Devonia Thus six genera of the Lucas unquestionably have Silurian affiniti These consist of one genus of coral (*Cylindrohelium* a new genus to whi Grabau doubtfully refers a Guelph species), and five genera of gastropo represented by species "mostly exotic in character." In view of t presence of unquestioned Devonian elements in the Lucas fauna, and the decidedly middle Devonian character of the faunas of the other upp Monroe divisions which underlie the Lucas, it seems decidedly inadvisab to place this whole formation in the Silurian on the evidence of gastropod which are admittedly "exotic," and are of a class of organisms know to be poor guide fossils in the Palæozoic system. It would seem mu more logical to consider the Detroit River series or upper Monroe as Devonian age, the Silurian species present being regarded as holdove from Silurian time. This is in accord with Grabau's alternative correl tion. He says[1]:

"If correlation were to be based on faunal evidence alone, a differe interpretation of the stratigraphy of Michigan would probably be adopte In that case, the lower Monroe would be correlated with the upper Ca ugan. . . . .

Faunally the upper Monroe might be considered as the indigenou lower Devonic. . . . . On this hypothesis, the Sylvania woul represent the continental condition appearing at the end of the Silu ric. . . . ."

Grabau, and Stauffer[2] as well, were greatly impressed with the erosio interval at the top of the Monroe formation, an interval sufficient to allo of the removal of the Lucas and Amherstburg dolomites from the top the Anderdon limestone at Amherstburg and Sibley before the Onondag sediments were deposited. This interval seemed to them to [illegible] th degree of magnitude required to separate systems. It must be remem bered, however, that the formations eroded were to a considerable exten magnesian calcilutites and calcarenites, or in other words dolomites forme from the erosion of other dolomites and hence the time required both fo their deposition and for their erosion would be much less than that require for the deposition and erosion of ordinary dolomite. As there was littl time for hardening, the erosion of these dolomites would undoubtedl be rapid.

That the time interval between the lower and upper Monroe ma have been at least as long as that mentioned above is suggested by th presence, between these divisions, of the continental Sylvania sandstone Grabau states[3] that there is reason to believe that the Sylvania sandston overlaps disconformably the different members of the lower Monroe, an even rests on the Niagara formation in Indiana. This indicates a muc greater erosion than that at the top of the Monroe. Again, in the character of the Sylvania sandstone good evidence of emergence and continental conditions exists, and the erosion at the top of the Monroe may so far as evidence goes, have been in part at least due to current action although the final conditions were those of emergence. Admitting, however, the difficulty in explaining the lack of sufficient sedimentary or other records which elsewhere might be expected to mark the long period required for the deposition of the upper Monroe and the erosion which removed a large part of it, it must be remembered that the difficulty is not removed but only shifted to Silurian time by considering the upper Monroe of Silurian age. The deciding element in the whole argument appears to the writer to be found in the fossils which are admitted by all to be Devonian in all essential characters.

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[1] Ibid. p. 233

[2] Geol Surv., Can., Mem. 34, p. 285.

[3] Ibid. page 56.

Although Stauffer formerly preferred to place the upper Monroe in the Silurian system, he has in his later writings given up this opinion. He says:[1] "It may be that the unconformity (disconformity) at the base of the Oriskany in western New York, represents the one occurring at the base of the Detroit River series, and that the unconformity (disconformity) at the top of the Oriskany is the one so prominent at the base of the Onondaga in Ohio, Michigan, and extreme southwestern Ontario. If this be the case, these two unconformities run together at various places in Ontario near the eastern end of lake Erie, but diverge rapidly to the westward from Springvale. There is thus represented an unknown interval during which it is probable the Detroit River series was deposited; for to maintain that such a fauna as that found in the Amherstburg dolomite is Silurian is more impossible than to find a place for it among the recognized Devonian formations."

Having settled the time classification to be adopted in this memoir for the Detroit River series, the age of the Sylvania sandstone has to be considered. Grabau concludes[2] that the sand, which may have been derived from the St. Peter or Potsdam sandstone to the west, was probably in part water and in part wind-borne at first, but later, as emergence continued, it was entirely wind-borne for a time, the sand dunes being reworked by the subsequent, advancing sea. This would account for the presence of Detroit River fossils in intercalated shale beds in the upper part of the Sylvania sandstone and for the intermingling of sand and dolomite as is found to be the case in the wells of western Ontario. Such a formation is typically tangential, and different parts of it may readily be assigned to different periods of time. In Ontario, however, the last phase of sedimentation seems to be predominant, and this fact, along with the content of Detroit River fossils in lenses near its top, favour placing the Sylvania at the base of the Devonian as here represented. As suggested in Stauffer's statement quoted above,[3] the thin lenticular sandstone at the base of the Dundee at Detroit river may represent the Oriskany horizon. That the purely æolian deposition may, as stated by Grabau in his alternative correlation of the Monroe formation, be classed as Silurian (better epi-Silurian) in the sense that it occurred during continental conditions at the close of the marine Silurian deposition, is possible, although improbable, as this would pre-suppose that the Sylvania sandstone bridged the gap occupied by the highest Silurian and the Helderbergian strata elsewher The classification adopted by the writer seems more satisfactory for t description of Ontario occurrences.

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[1] Bull. Geol. Soc. Am., vol. XXVII, 1915, p. 77.
[2] Ibid, page 79
[3] Ibid, page 76

In adopting the above classification, the terms upper Monroe an lower Monroe are obviously no longer appropriate, since the so-calle Monroe is now seen to belong to different geological systems. Grabau alternative names "Detroit River" and "Bass Island" will hence used.

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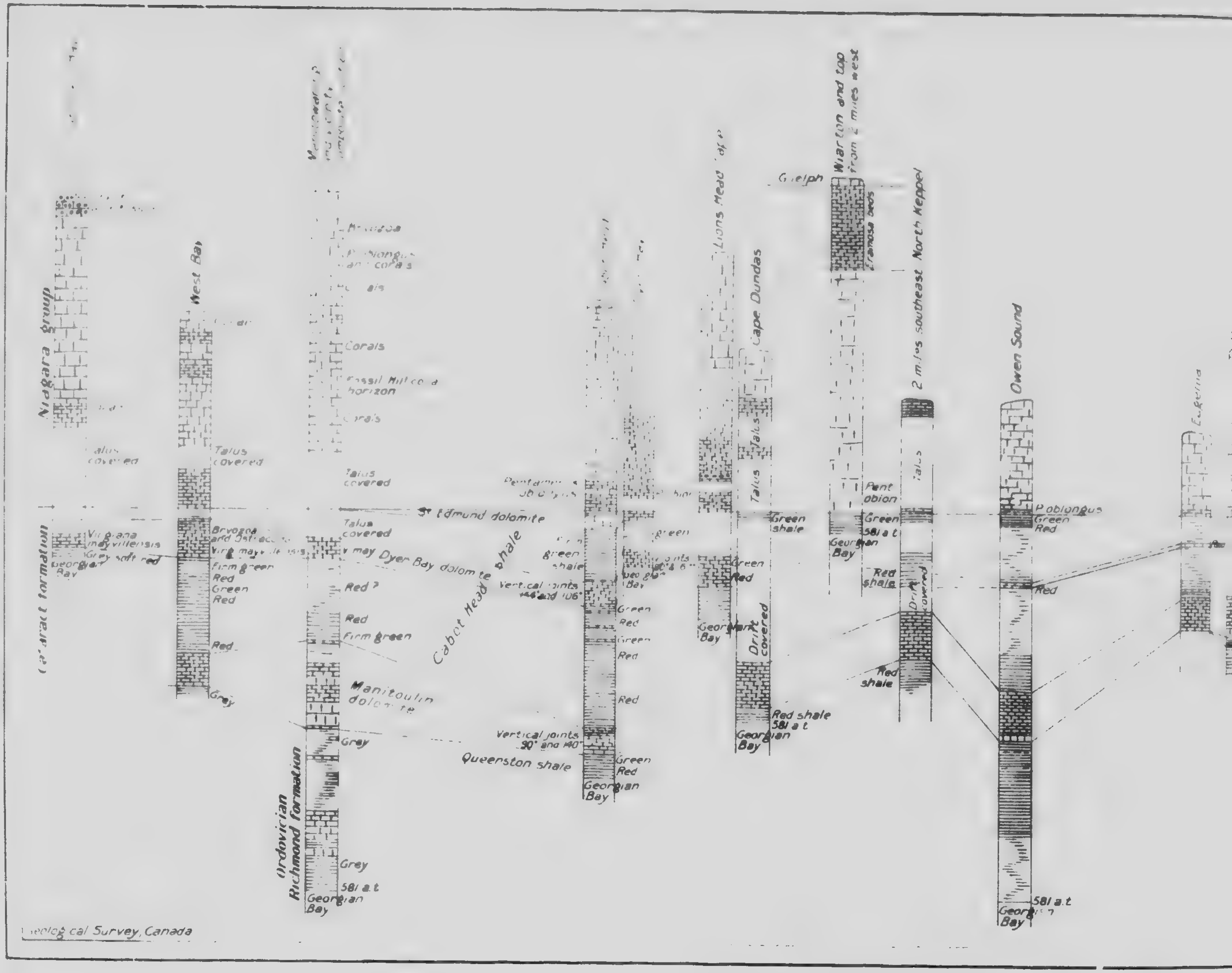
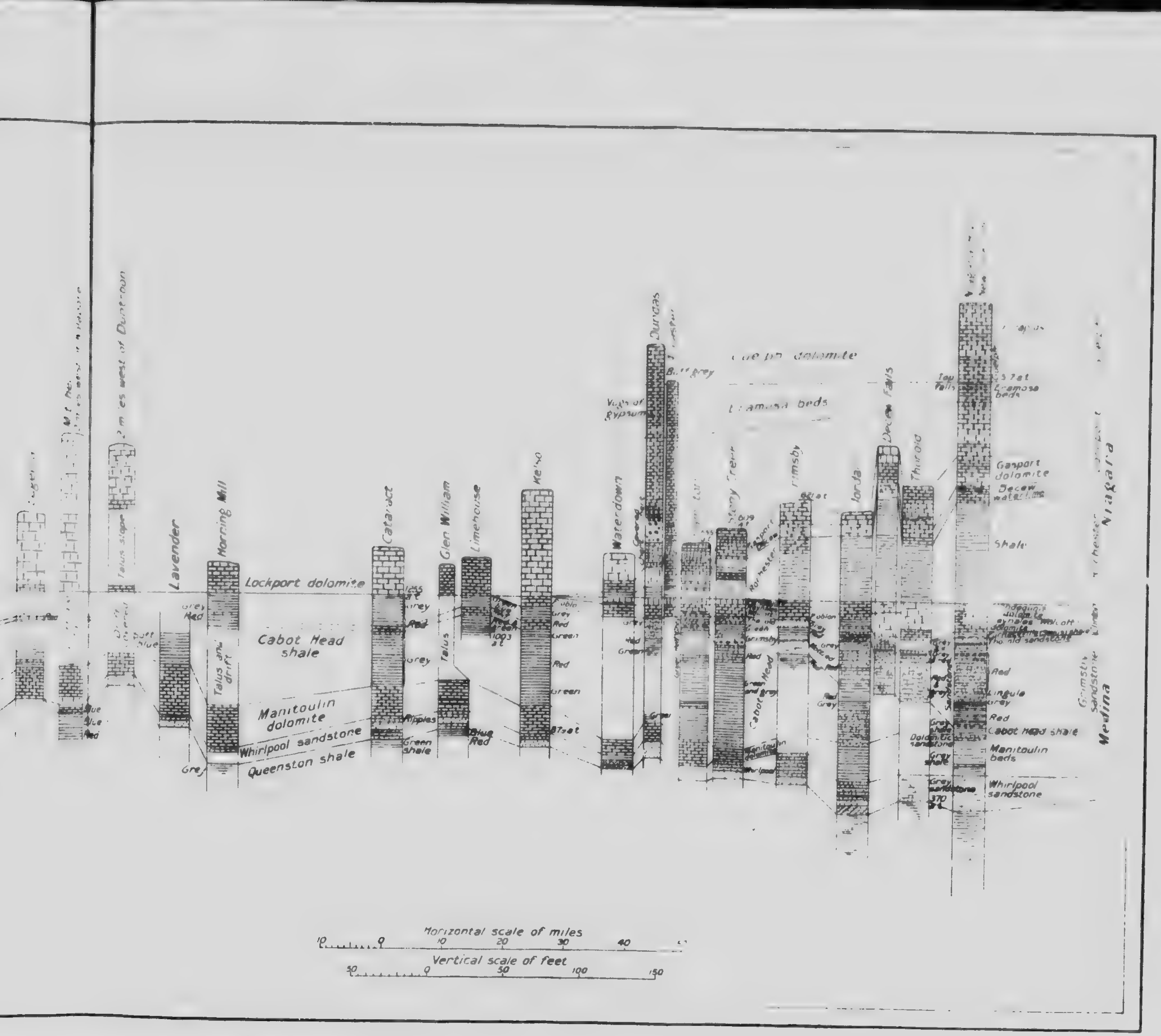


Figure 3. Diagram showing sections along the Niagara escarpment

Memoir by M. Y. Williams



…scarpment of Ontario peninsula and Manitoulin island.

Sections prepared from surveys by M Y Williams, 1913 1916

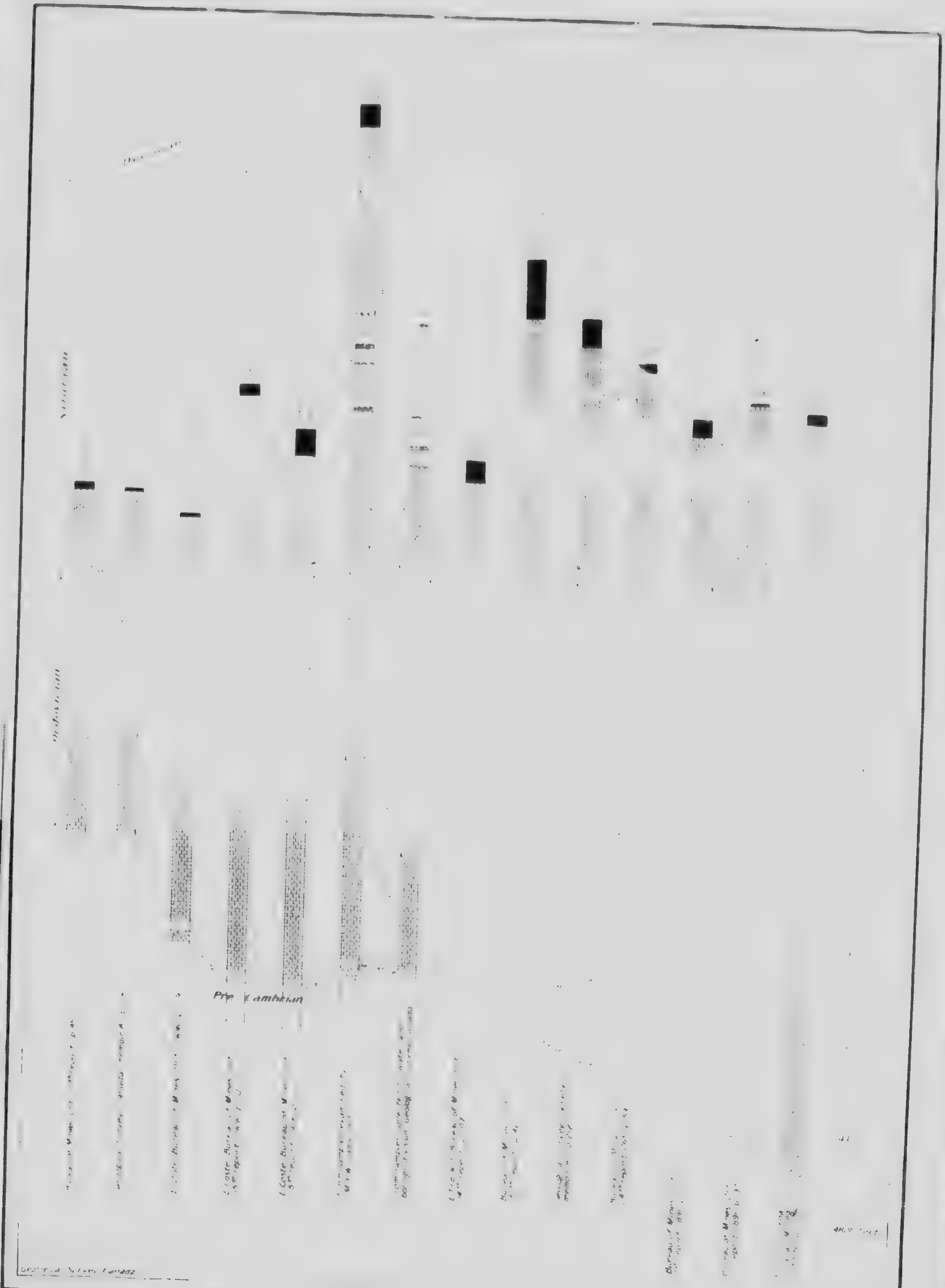


Figure 4. Characteristic geological sections in Ontario peninsula prepared from records of borings, the base of the Silurian [illegible] is the plane of reference

To accompany Memoir by M. Y. Williams

CHAPTER V.

DESCRIPTION OF FORMATIONS.

THE MEDINA-CATARACT FORMATION.

EXPLANATION OF NAME.

The Ontario sediments of the Medina-Cataract formation vary so distinctly by lateral gradation that a hyphenated term seems best suited for the name of the formation as a whole. The term Medina, as restricted by Grabau, is applicable to the formation at Niagara Falls and may be extended to Hamilton, if minor changes are overlooked. It would thus include the sediments between the Queenston shale below and the Clinton formation above, the subdivisions in ascending order consisting of the Whirlpool sandstone, the Manitoulin beds more or less developed into dolomite (a decided dolomite at Stony Creek and Hamilton), the Cabot Head sandy shales, the Grimsby sandstone (thin at Hamilton), and the Thorold sandstone (absent at Hamilton). The term Cataract as defined by Schuchert is applicable from Dundas (and fairly applicable at Hamilton which is in the transition zone) north, and includes the Whirlpool sandstone, the Manitoulin dolomite, and the Cabot Head shale which contains in its upper half on Bruce peninsula and Manitoulin island the Dyer Bay and St. Edmund dolomites. The littoral deposition of sand forming the Whirlpool sandstone terminated southwest of Collingwood and the Grimsby and Thorold sandstones grade northward into mudstones and sandy shales of the Cabot Head shale division, probably because of the lack of sandy material due to the distance from its source. As may be seen from Figure 3, the Cataract rests successively to the north upon the Queenston and marine Richmond sediments and is overlain successively by the Clinton and the Lockport dolomites.

GENERAL DESCRIPTION.

The term "Medina," as already stated, is here used in the restricted sense defined by Grabau,[1] that is to include the "upper Medina" of the older reports or the sandstones and shales between the Queenston shale below and the Clinton formation above. Believing that the Queenston shale is separated from the "upper Medina" by a systemic boundary, Grabau found it impossible to use the term Medina to include the "upper Medina" and the Queenston shales as had formerly been done, and he concluded that the term was first referred to the section near Medina, New York, where the upper division is the prominent one. The term Cataract includes the so-called "Ontario Clinton" and the Whirlpool sandstone, or the sandstones, dolomite, and shale between the Queenston, or in the north the Richmond, below, and the Clinton, or farther north the Lockport, above. From Hamilton north "Cataract" is used exactly as defined by Schuchert, the author of the term. The present usage,

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[1] Science, new ser., vol. XXIX, 1909, p. 356.

not the conception of the facts, however, differs from that of
in the Niagara peninsula, where Schuchert restricts the term
to the Grimsby and Thorold sandstones (described below), using
Cataract for the lower members of Grabau's Medina. There i
accord, however, in the belief that the Grimsby and Thorold sa
are only facies of the top of the Cabot Head shale occurring farth
although they represent another faunal invasion. Briefly, the
contention is that the term "Medina" should be used for as mu
formation formerly included as is possible, and as restricted by
is applicable throughout the Niagara peninsula, and that the term
is entirely necessary and is properly applied to the sections from
north where the phases of sedimentation exclusive of the Whirlp
stone are so different from that of the Medina that the sedime
formerly classed as "Clinton". In referring to the whole of south
O[illegible], the hyphenated term, Medina-Cataract, seems most sati
The names of sub-divisions, like Cabot Head shale, may, how
used wherever the distinguishing characters are present.

As already stated the Cataract formation above the Whirlp
stone was formerly thought to be Clinton. This was because
following considerations: the thinning out of the Clinton limesto
the overlying Rochester shale from Niagara river westward; the
ment of the Manitoulin dolomite in the same region; the disap
of the Thorold sandstone or Grey Band of New York, in the vi
Hamilton; and the wrong interpretation of the Whirlpool sand
the "Grey Band" from Hamilton north. These mistakes are mor
evident in the "Palæontology of New York" vol. II, 1852, and
evident in the "Geology of Canada", 1863, and Logan, to some ext
the difficulties involved. On page 322, he says "The bluish-blac
which in the state of New York afford a well-marked division betw
Clinton and Niagara formations, are available for this purpose,
a short distance in Canada...... We, therefore, propose to in
the Niagara series, the two bands of limestone which unde
shales, and which, in New York, constitute the upper part of the
formation." The Cataract fossils, particularly those collected at H
and Dundas (e.g. *Cœlospira planoconvexa*, etc.) were figured by Ha
with the true Clinton fossils, and subsequently palæontology was
back up the error in stratigraphic determination. Confusion reigne
transition zone between Hamilton and Niagara river where b
Medina and Cataract characters are fairly well-marked, but from H
north the dolomite and shale of Medina age were unhesitatingly
as "Clinton". The "Clinton" of Ohio, in part thought to corre
age with the Cataract, formed another anomaly and it was only a
tangle was straightened out by Schuchert for Ontario, that harm
finally attained. Such differences as may exist in recent publicati
rather matters of terminology than of interpretation of facts. The
study of the northern sections by the author in 1915-16 has adde
tional information relating to the top of the Cataract section a
corrected interpretations of the author which were embodied in Sch
account of the Cabot Head region.

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[1] Palæontology of New York, vol. II

Following is a description of the members of the Medina-Cataract formation, taken in ascending order.

WHIRLPOOL SANDSTONE[1] MEMBER.

Extent and Characteristics.

From Niagara river to the vicinity of Duntroon, about 8 miles south of Collingwood, the Whirlpool sandstone is the basal member of the Medina-Cataract formation, and so the oldest representative of the Silurian system. The typical sandstone consists of fine quartz grains, is light grey in colour, and is in part crossbedded. At some localities, notably in the vicinity of Credit Forks, chocolate-brown beds occur interbedded with the grey. From a thickness of 25 feet at Niagara river and 30 feet reported from a well boring at Thorold, the Whirlpool sandstone thins to the west and north, being 4 feet thick at Glen Huron and 6 feet thick, 3 miles west of Duntroon. At Mitchell's mills, 2 miles west of Kolapore, 6·5 feet of green shale with sandy beds at the base, may represent an offshore occurrence of the Whirlpool sandstone. This is the extreme northwesterly occurrence known to the writer.

West of the Niagara escarpment, the information relating to the extent of the Whirlpool sandstone is derived from records obtained from well borings. In spite of the devious methods by which many of these records have been kept, a fair idea of the geographical distribution of the sandstone may be obtained from them. Thus we learn that no sandstone occurs at the top of the Queenston west of the city of Guelph, neither is any present at Kitchener, London, Petrolia, nor in Kent county. At Beachville, calcareous sandstone is reported, which may represent the Whirlpool sandstone, in part reworked at a later time. In Colchester township, Essex county, 62 feet of sandy limestone occurs at the Manitoulin dolomite horizon and the sand content may represent the Whirlpool deposition. In Norfolk county, the Whirlpool sandstone is reported to be 5 feet thick at Port Burwell, 23 feet at Vienna, 27 feet at St. Williams, 10 feet at Vittoria, 18 feet at Port Ryerse, 12 feet at Port Dover, and 3 to 5 feet in the vicinity of the town of Simcoe. Thicknesses are reported elsewhere as follows: in Haldimand county, between 10 and 30 feet; in Welland, 19 feet at Port Colborne and 30 feet at Thorold; and near Brantford between 10 and 20 feet. From the above evidence (omitting the uncertain evidence from Essex county) the western underground extension of the Whirlpool sandstone may be limited within our knowledge by a line drawn from a point near Duncan, 13 miles southwest of Collingwood, southeasterly past Heatherton and thence southerly between Guelph and Kitchener, and southwesterly to lake Erie near Port Stanley.

The Whirlpool sandstone everywhere rests on the red Queenston shale, which is almost universally mud-cracked at the top, the sand-stone projecting down into, and filling the cracks. In general, the lower half of the sandstone is thick-bedded to massive, the upper half is thin-bedded, and, where overlain by shale, grades into the overlying beds, through a transition zone of alternating sandstone and shale. Crossbedding observed in some part of almost every section, but is confined to a limite thickness. Shale lenses occur here and there in the crossbedding. Wit the overlying Manitoulin dolomite the contact is sharp, but the lowe dolomite beds are arenaceous. At Glen William, ripple-marks occur i the upper bed of sandstone, and at Credit Forks oval masses of sandston are enclosed in shale coverings, which are in many cases full of wor burrows. The upper beds of the sandstone here are undulatory, an "pillow" structure occurs locally, at the very top. One specimen "pillow", about 2 feet long, is shaped like a sheaf of wheat with shal containing casts of worm burrows or fucoids wrapped around its side an partly over one end. Ripple-marks occur on some of the "pillows". Th base of the overlying dolomite is full of vugs of pink celestite.

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[1] Jour. Geol., vol. XVII, No. 3, p. 238.

North and west, from the vicinity of Dundas, the Whirlpool sandstone was described by Sir Wm. Logan (Logan 1863, p. 313) under the name of "Grey band." The true "Grey band" of former writers, now known as the Thorold quartzite, does not occur to the west and north of Hamilton and as a consequence, Logan confused the more northern occurrences of the Whirlpool sandstone with it.

Under the microscope, typical Whirlpool sandstone taken from on of the "pillows," is seen to be made up of angular to subangular quart grains of 0·1 mm. average diameter. No secondary quartz was observed but there is recrystallization indicated by wavy extinction, along th margins of the sand grains, which are closely compressed, in interlockin arrangement.

Fossils are of rare occurrence in the Whirlpool sandstone and ar found for the most part in the upper beds. The following have bee obtained by the writer and his assistants. *Pleurotomaria* sp. (fragmentary) *Hormotoma subulata* Hall? ?*Cornulites*, and casts of worm burrows o castings and fucoids (see Table and Plates II, III, and VIII).

Origin.

The origin of the Whirlpool sandstone is a subject of some interest A. W. G. Wilson[1] has described the Whirlpool sandstone ("grey band" of Ontario) as of probable sand dune origin, and cites the mud-cracked character of the upper Queenston shales, and the crossbedding of the Whirlpool sandstone itself, in support of his contention.

Grabau[2] derives his "Medina red sands" and "Thorold quartzite" from the erosion of the folded Juniata beds and Bald Eagle quartzites o the Appalachian region. He says of the Whirlpool sandstone.[3] "A. W. G. Wilson has interpreted this lens of sandstone as the remnant of an old dune area, reworked by the advancing sea, and this interpretation is favoured by the character of the grains composing this rock as well as by its distribution. Some of the bedding surfaces of this quartzite show wave-marks closely resembling those of modern shallow beaches, a feature repeated in a number of higher beds farther east. The Whirlpool quartzite is not known at Rochester . . . . The Whirlpool quartzite is thus seen to be a local formation apparently unconnected with any direct eastern source."

That the shales and sandstones of the Queenston and Medina beds were derived in general from the Appalachian region, there seems little reason to doubt, and it appears to the writer that though the "Whirlpool quartzite" may be "apparently unconnected with any direct eastern source" its deposition may be readily explained as the result of geological processes at work after Queenston time.

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[1] Can. Rec. of Sc., vol. IX, No. 2, 1903, pp. 120-122.
[2] Bull. Geol. Soc. Am., vol. XXIV, 1913, pp. 444-445.
[3] Ibid. page 461.

Grabau has hypothecated the erosion of Bald Eagle beds to supply the material of the Thorold quartzite. No good reason is apparent why these beds may not have been eroded to some extent at least, before the Thorold deposition. As might be expected, the Queenston shales are more arenaceous in the east, nearer their source, and it is more than probable that sand bars of river origin, flood-plain deposits of gravel and sand, and possibly piedmont deposits of coarse materials characterized their landward extension during their period of deposition.[1] The nearby old land might be expected to furnish such deposits. With the return of shallow water conditions indicated by mud-cracks in the Queenston shales of western New York and Ontario, rejuvenation of the erosion processes would follow, and though shale would be carried farther seaward, a littoral zone would receive the sandy deposits. Wind may have played a large part in the distribution of the sand over the mud-cracked Queenston surface or gentle currents may have been the distributing factor. Again, the cleanly sorted, even-grained nature of the Whirlpool sandstone, although due no doubt in great measure to its long transportation by stream action and to subsequent wave action in the littoral zone, may be dependent to some extent upon the effective sorting done by the wind. The fact that from Rochester eastward the Whirlpool sandstone has not been recognized, may be explained on the ground that sorting has been less effective and consequently the red sandstone of contemporaneous age with the Whirlpool cannot be distinguished from similar beds above and below. It is difficult indeed to determine the boundary between the Queenston and Medina sandstones from Rochester eastward.

Thus the origin of the material of the Whirlpool sandstone very probably dates back to the emergent period marking the interval between Ordovician and Silurian time. That the Whirlpool sandstone has received its present form during the advance of the sea at the commencement of Silurian time is shown by the following characters: (1) the formation has a comparatively uniform thickness; (2) crossbedding is limited to a part of the beds only and is more regular than is that characteristic of wind deposition; (3) the upper beds are generally thin, and are interbedded with shale or contain pillow structure; (4) the upper beds are sparingly fossiliferous, the fauna being characteristic of the marine littoral zone.

Shale occurs in the crossbedded sandstone at Credit Forks, but this may be the case even in aeolian deposits as shown by Grabau.[2]

As will be shown later, subaerial distribution of the Whirlpool sand over the semi-emergent Queenston surfaces may readily have resulted in alternating sand and shale beds on the invasion of the Silurian sea. Easterly trade winds at this time, as suggested by Grabau,[3] would appear to fulfil the required conditions. Whether such winds existed or not the emergence of the land would readily account for seaward extension of the coarser clastic deposits as described by Wilson.[4]

[1] Bull. Geol. Soc. Am., vol. XXIV, No. 3, 1913, p. 494.
[2] Principles of stratigraphy, p. 584.
[3] Grabau, A. W., "Palaeozoic delta deposits," pp. 440 et seq.
[4] Wilson, A. W. G., Can. Rec. Sc., vol. IX, No. 2, 1903, pp. 113.

Fauna of Whirlpool Sandstone.

Gastropoda.
  Pleurotomaria sp. Niagara River.
  Hormotoma subulata (Conrad)?? Glen William.
Vermes (burrows and trails).
  ?Cornulites.

MANITOULIN[1] MEMBER.

General Description.

At its typical occurrences, on Manitoulin island, the Manit member which rests on Richmond shale and is overlain by Cabot shale is a resistant, thin to thick-bedded, grey or buff-weathering dolo which when fresh, is hard and of light, blue-grey colour. Near the the dolomite is thin-bedded and argillaceous; midway up beds 10 fe more in thickness occur; and thin beds are again present near the top. escarpment of Manitoulin dolomite, about 1 mile east of the hea Manitowaning bay, measures 50 feet in height, so that allowing for g tion and other erosion, the total thickness here must have been at 60 feet.

In the vicinity of Manitowaning, local coral and bryozoan occur in the upper 20 feet of the dolomite. The reefs are several y in diameter, and cause local thickening of the dolomite and c structure.

At Cabot Head lighthouse, the Manitoulin dolomite is about 10 thick, but beds occur to the westward which give an indication tha total thickness is 25 to 30 feet. At Owen Sound, 32 feet of this dolo is exposed in a quarry, the rock being thin-bedded, and of grey c with blue shale partings. From 23 feet at Credit Forks, the thickne the dolomite decreases to the southeast to 8 feet at Stoney Creek, be which the dolomite gives place to calcareous shales. At Niagara g a 3-foot bed of calcareous sandstone rests on 25 feet of shales. sandstone appears to represent the southeastern extension of the up most of the Manitoulin beds.

Well records give the Manitoulin dolomite as 15 to 20 feet thic Brantford; 42 feet thick in Pilkington, and 29 feet in Peel town Wellington county; and 50 to 60 feet thick between Allenford and Wia At Woodstock 35 feet of calcareous sandstone is reported and in the we part of Kent county the Manitoulin dolomite is 20 to 50 feet thick. a record of a well in Colchester South township, Essex county, 62 fe "grey blue and white sandy limestone" is reported from the Manito horizon. It is consequently fairly certain that excepting the calcar shales and sandstones at the Manitoulin horizon in the eastern and sout part of the Niagara peninsula, the Manitoulin dolomite underlies whole of the Silurian area of southwestern Ontario. Where such are not reported it is by no means certain that they are absent, as may easily have been overlooked in keeping the well records.

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[1] Proposed by author, Ottawa Nat., vol XXVII, 1913, p 37. Formerly proposed by A. C. Lane, Geol Mich., vol I, 1873, as a group name to include Niagara and Guelph. This usage is not generally recognized

In the south, the Manitoulin beds rest on the Whirlpool sandstone. Even where the basal beds are shale, the contact is well-defined, but transitional sandstone and arenaceous shale alternate above the top of the well-defined Whirlpool sandstone. Where dolomite rests on the sandstone, the contact is generally sharp, but the lower dolomite beds are sandy or arenaceous. The dolomite rests with sharp, even contact on red Queenston shale from Collingwood west and north to the end of Bruce peninsula, the Queenston last being seen at Cabot head. On Manitoulin island the contact is with green Richmond shale. This contact is sharp, but the basal Manitoulin dolomite is somewhat argillaceous. The two faunas have practically nothing in common.

Microscopic Characters.

A specimen of fresh Manitoulin dolomite from a quarry at Owen Sound, proves under the microscope to be composed of interlocking grains of dolomite of 0·12 mm. average diameter.

Two specimens of the dolomitic sandstone of Niagara river were examined microscopically. One proved to be made up of rounded quartz grains of 0·13 mm. average diameter, with about 50 to 55 per cent dolomite. The other is composed of rounded to subangular quartz grains of 0·10 mm. average diameter, and 5 to 15 per cent of dolomite. One, small, worn fragment of plagioclase was observed in each slide, the size corresponding to that of the average quartz grains.

The arrangement of the crystals of dolomite indicates that they have crystallized around and have filled in pore spaces between the quartz grains.

Under the high power, the edges of the quartz grains are found in many cases to be gently etched, indicating some solution by the highly charged dolomitic waters which surrounded them.

Fossils.

As will be seen from the table (page 30 and Plates III, V, VI, and VII) the Manitoulin dolomite is for the most part decidedly fossiliferous.

Origin.

Of the origin of the Manitoulin dolomite, Grabau says[1]: "The Keppel (previously named Manitoulin by the author) dolomite is an earlier deposit before the sands and muds from the Appalachians reached this point, or during the earlier period of the erosion of the folded red beds of the Ordovicic." Schuchert[2] says "the Cataract province spreads westward through the Saint Lawrence embayment", and concludes "that the normal marine junction of the Cataract and Brassfield seas is prevented by the Medina delta".

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[1] "Palæozoic delta deposits," p. 460 cf 469.

[2] "Medina and Cataract formations of the Siluric of New York and Ontario", Bull. Geol Soc. Am, vol XXV, p. 294

Fauna of Manitoulin Dolomite.

Genera and species.	Niagara River	Grimsby	Stoney Creek.	Hamilton	Dundas	Glen Williams	Cataract and Credit Forks.	Lavender falls	Banks	Rockside	[illegible]	Owen Sound	Cabot Head	Church Hill	Manitowaning	Heron	West Bay	Kagawong	Gore Bay
Plants																			
Buthotrephis gracilis crassa Hall				x			x												
Hydrozoa																			
?Clathrodictyon vesiculosum (Nicholson and Mur.							x												
Anthozoa																			
Streptelasma cf. hoskinsoni Foerste			x				x		x	x				x	x				x
Enterolasma cf. geometricum (Foerste)			x	x		x	x	x	x						x			x	x
Zaphrentis bilateralis (Hall)															x				
Palæophyllum umbellicrescens Chadwick															x				
Palæophyllum (Cyathophylloides?) williamsi sp. no.															x				
Amplexus shumardi (Edwards and Haime)														x					
Chonophyllum belli Billings															x				
Acervularia gracilis (Billings)															x				
Ceratopora tenella (Rominger)						x									x				
Syringopora retiformis Billings													x		x				
Palæofavosites asper D'Orbigny				x									x	x	x	x		x	x
?Halysites catenularia microporа Whitfield															x				
Cystidea																			
Brockocystis tecumseth (Billings)												x	x		x		x	x	x
Crinoidea																			
Eucheirocrinus ontario Springer n. sp.			x																
?*Bryozoa*																			
Homotrypa? confluens (Foerste)						x													
Hallopora magnopora (Foerste)						x									x				
Helopora fragilis Hall	x																		
Pachydictya turgida Foerste															x				
Brachiopoda																			
Lingula cuneata Conrad	x																		
Strophonella striata Hall							x	x				x	x	x	x				x
Leptaena rhomboidalis (Wilckens)			x	x		x	x	x	x			x	x		x	x		x	
Plectambonites transversalis (Wahlenberg)																			

Pachydictya turgida Foerste															x				
Brachiopoda																			
Lingula cuneata Conrad	x																		
Strophonella striata Hall							x	x				x	x	x	x				x
Leptaena rhomboidalis (Wilckens)			x	x		x	x	x	x			x	x		x	x		x	
Plectambonites transversalis (Wahlenberg)			x	x					x										
Orthis flabellites Foerste			x			x	x	x				x	x		x	x	x	x	
Hebertella fausta (Foerste)			x	x					x										
Platystrophia biforata (Schlotheim)			x	x					x										
Dalmanella eugeniensis Williams n. sp							x		x			x	x	x	x		x		x
Dalmanella eugeniensis paleoelegantula Williams n. var							x	x		x	x				x		x	x	x
Rhipidomella hybrida (Sowerby)			x			x	x	x	x										
Camarotoechia (Stegerhynchus) neglecta (Hall)			x	x			x	x					x	x	x				x
Rhynchotreta cuneata americana (Hall)								x						x	x		x		
Rhynchotreta williamsi Foerste n. sp																			
Rhynchotreta cabotensis Williams n. sp			x												x				
Rhynchonella? janea Billings					x				x						x				
Rhynchonella? bidens Hall																			
Atrypa parksi Williams n. sp			x	x	x		x								x				
Whitfieldella cataractensis Williams n. sp	x			x		x	x	x						x	x		x	x	
Coelospira planoconvexa (Hall)		x		x	x		x					x	x	x	x		x	x	
Gastropoda																			
Bucanella trilobata (Conrad)	x																		
Bucania cf exiguus Foerste															x				
Lophospira pulchra Williams n. sp																			
Strophostylus cancellatus (Hall)			x																
Hormotoma subulata (Conrad)															x				
Cephalopoda.																			
Orthoceras ignotum Foerste									x										
Orthoceras hanoverensis Foerste																			
Orthoceras multiseptum Hall																		x	
Vermes.																			
Cornulites distans Hall			x	x		x													
Cornulites incurvus (Shumard)				x				x											
Trilobita.																			
Calymene clintoni (Vanuxem)			x			x			x										

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[1] Reported by Parks, Twelfth Inter. Geol. Cong., Guide Book No. 5, 1913 p. 30.

[2] Identified by Bassler

Although described by the two writers from widely divergent v points, one idea is back of both statements, that is, an encroachin from the northward, tending to deposit calcareous material, was inv by detrital material from the Appalachian province. The greater th ness of the Manitoulin dolomite in the north and the sandy shaly pl of this member in the south, indicate quite clearly the encroachin fairly deep, marine conditions over the littoral zone occupied by Whirlpool sandstone. That the supply of detrital material became g in post-Manitoulin time than the deposition of calcareous deposits is sh by the shaly or sandy characters of the subsequent members of the Cat formation.

CABOT HEAD SHALE MEMBER.

General Description.

The Cabot Head shales, as already explained, were formerly incl with the Manitoulin dolomite in the Clinton formation of Ont. Schuchert[1], in 1912, included these shales in the Cataract formation in 1913 the author[2] proposed for them the name "**Kagawong** mem or "**Kagawong** shales." This name was preoccupied by Foerste had applied it to an upper Richmond member. "*Cabots Head*" proposed by Grabau[3] in 1913 for the red and grey Cataract shales included dolomites of the mainland of Ontario. In its corrected f "Cabot Head" (following the recognized form of the place name on maps charts), the author finds it applicable for the Cataract shales of southw ern Ontario and the Georgian Bay region.

Detailed Description and Sections.

The Cabot Head shales vary much in character in different part the same section, as well as at different localities. They include g and red shales and fine-grained, shaly sandstones, ferruginous, sa dolomite, and grey, shaly dolomite. At Niagara river, where some sa dolomitic beds and grey shales below them are classed as a southern fa of the Manitoulin dolomite, only 3 or 4 feet of grey shale are classifie Cabot Head. Here, the Grimsby sandstones are thick and characte tically developed. As they become shaly to the north they add to thickness of the Cabot Head shales of which they are a southern fa The general colour of the shales from Niagara river to Wiarton is g but red, sandy beds occur in the upper half including a red, sandy, d mitic bed well exposed at Kelso, Limehouse, and Cataract. The sha of Bruce peninsula and Manitoulin island contain red beds in their lo half and beds of dolomite interbedded with grey shale in their up half.

At no place do the Cabot Head shales show more variations t at the type locality of Cabot head. The nearly flat-lying Manito dolomite at Wingfield basin, upon which Cabot Head lighthouse sta dips gently to the southwest beneath the escarpments of three promi bluffs, known locally as Bowlder, Middle, and West bluffs. Talus obscures much of the section, but as worked out it consists in ascending order of 70 feet of shale, red near the base and containing firm beds bearing *Helopora fragilis*, and firm and green near the top; 4 feet of soft green shale; 15 feet of thin, even-bedded dolomite (Dyer Bay); 32 feet of firm green shale; 8 feet of rather massive, creamy weathering dolomite (St. Edmund); and 4 feet of soft, green shale. Lockport dolomite succeeds, the lowest 8 feet being thin-bedded, green in colour, and in part mud-cracked.

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[1] Bull. Geol. Soc. Am., vol. XXIV, 1913, p. 107.

[2] Ottawa Naturalist, vol. XXVII, pp. 37-38.

[3] Bull. Geol. Soc. Am., vol. XXIV, No. 3, [illegible], 1913, p. [illegible]

The above section was described by Logan[1] and copied by Grabau[2]. Logan's description follows: "At Cabot's Head, the very summit of the Medina formation "(Queenston)" is seen at the water's edge; and there rest upon it about twenty-six feet of a dolomite . . . . On the dolomite, repose 103 feet of red, marly sandstones, partially striped and spotted with green, and inter-stratified with beds of red and green argillaceous shale; none of which exceed six or eight inches in thickness. The green argillaceous beds appear to be quite free from calcareous matter, and the stone is carved by the Indians into tobacco pipes. These red and green strata are succeeded by about fifty-five feet of green calcareo-argillaceous shales and thin-bedded limestones, and terminated by the massive limestones of the Niagara series."

Three miles west of Cabot head, a fine exposure, locally known as the "Clay cliffs,"[3] occurs on the shore (Plate XXXIA). The Manitoulin dolomite is here below the water, the section being, in ascending order from the water up, as follows: lower 22 feet obscured by talus, probably red shale; 5 feet of soft, red shale; 17 feet of soft, red shale, interbedded near the base with thin calcareous shale, and containing also firm shale beds to about one-fifth the total amount; 3 feet of green clay shale; 15 feet of massive to thin-bedded dolomite (Dyer Bay); 36 feet of thin-bedded, firm, green shales; 8 feet of buff-weathering dolomite (St. Edmund) containing *Favosites cristatus*; 14 feet of covered interval, succeeded by 4 feet of dolomite belonging to the Lockport formation and bearing *Pentamerus oblongus*. From a comparison with the Cabot Head section it is evident that the upper 8 to 10 feet of the covered interval includes thin dolomites belonging to the base of the Lockport formation and that only the lower few feet are shale beds.

The upper dolomites ("limestones") were clearly included by Grabau in the Cabot Head shales, and so there appears no good reason for redefining the term. Ferruginous limestone is found near the top of the Cabot Head shales at Credit Forks and Limehouse, and thin-bedded dolomites occur interbedded with shale in the upper part of the Cabot Head beds on Manitoulin island. The dolomite beds at Cabot head appear worth of some designation, particularly as they carry, as will be described lat characteristic fossils. It is proposed to designate the lower, the D Bay dolomite lentille, and the upper, the St. Edmund dolomite lent The lower dolomite contains numerous characteristic fossils at Dyer B and St. Edmund is the township in which the clay cliffs are situated an there the upper dolomite is best exposed. These dolomites are describe in detail below.

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[1] Geology of Canada, 1863, pp. 312-320.

[2] Ibid., page 460.

[3] On seeing the section at the Clay cliffs, for the first time, the author confused the 15 feet of dolomite in it with the Manitoulin dolomite at Cabot head, and as a covered interval at the base of Centre and West bluffs suggested a structural break, he stated in the Summary Report of the Survey for 1913 (p. 183) as follows: "Cabot Head was proposed by Grabau for the shale under discussion and it is here accepted. The writer, however, wishes to draw attention to the fact that the measurements and description of the section at Cabot head, which were taken from Logan, are seriously in error, due to the failure on the part of former workers (and the writer also upon a previous occasion) to recognize a structural disturbance, which repeats much of the section." For the same reason the thickness of these shales is given in the Summary Report for 1912 (p. 279) as 50 feet. Likewise the plate published by Schuchert (a) which was taken from a photograph by the author, is wrongly described in the title. In reality it is the 15-foot bed of dolomite (Dyer Bay) high up in the Cabot Head shales. The true Cataract (Manitoulin) dolomite is here submerged. The section given by Logan, though differing slightly in measurement, is substantially correct, as may be seen by a comparison with the section by the author given above.

(a) Bull. Geol. Soc. Am., vol. XXV, 1914, pl. 14, fig 2, opposite p. 287.

The Cabot Head shales on Fitzwilliam and Manitoulin islands a in general soft, red, clay shales in their lower beds, but contain soft, gre shales, firm, green shales, and dolomites (Dyer Bay) near the top. Th at the northeastern extremity of Fitzwilliam island, 15 feet of soft, r clay shale is overlain by 6½ feet of soft, green shale and thin, firm, gre shale interbedded. West of Tamarack cove, in a partial section, sof green shale is overlain by 15 feet of green-grey, fine-grained dolomi (Dyer Bay) which is succeeded by 22 feet of firm, pea-green shales. covered interval obscures the beds above

In the partial sections along the east side of lake Manitou son firm, green shale occurs above 10 to 15 feet of exposed, red shale, whic where exposed at another place, overlies firm, green shale. On the ro between West bay and Kagawong, the section from the Manitoulin dol mite up is as follows: 40 feet of soft red shale; 1¾ feet of hard, gre shale, calcareous at the base; 10 feet of soft, red shale; 5 feet of soft, gre shale; succeeded by fine-grained Dyer Bay dolomite. Red shale w also observed one-half mile west of Ice lake along the road to Gore B (27 feet of shale exposed); near the site of the former Indian village Campbell bay; and at water level at the end of the point between Campb and Helen bays. Red clay is also reported along the east side of l Wolsey

Southward from Cabot head, both the Dyer Bay and St. Edmun dolomites extend to Dyer bay; the Dyer Bay is seen at Gun point a both are missing on Colpoy bay. From Owen Sound east and sout as already stated, the lower Cabot Head shales are green or grey, t upper red, containing ferruginous limestones. Thin, calcareous be occur throughout the section, and arenaceous (sandy) beds and th sandstones are common in the southern sections. The Cabot He shales are 110 feet thick at Owen Sound, 60 feet at Cataract, 42 feet Hamilton, 66 feet at Stoney Creek, 63 feet at Jordan, and 5 feet at Niaga river. At the last-named locality, the beds consists of grey shale a thin sandstone, the grey and red sandstone above being included in t Grimsby sandstone which appears to be clearly the sandstone phase [illegible] Cabot Head shales occurring to the west and north.

Depending upon the evidence obtained from well records, there a from 15 to 65 feet of Cabot Head shales at Port Burwell, 65 feet at Bea ville, 30 at Glen Allen (24 miles northwest from Guelph), 75 to 100 f [illegible] of lake St. Clair, and 100 feet in Colchester township, Essex coun Although some well logs do not clearly show the presence of Cabot H shale, enough has been learned to make it seem probable that the C Head shales extend (underground) to the southwestern li [illegible] Ontari

For the fossils of the Cabot Head shales see t Plates IV, V, and VII.

Fauna of Cabot Head South, Exclusive of Dyer Bay and St. Edmund Dolomites.

Genera and species	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Hall				
Receptac[illegible]				
[illegible]				
Streptelasma hoskinsoni [illegible]				
Zaphrentis turbinata Hall				
Favosites [illegible]				
Hel[illegible]				
[illegible]				
Strophonella striata Hall				
Leptaena rh[illegible]				
Plect[illegible]				
Orthis flabel[illegible]				
Hebertella fausta [illegible]				
Platystrophia [illegible]				
Dalmanella eugeniensis Wi[illegible]				
Rhipidomella hybrida (Sow[illegible]				
Camarotoechia [illegible]				
Rhynchotreta? [illegible] Hall				
Rhynchonella? [illegible]				
Cyrtia [illegible] Williams n. sp.				
Whitfieldella cataractensis W[illegible]				
Coelospira plano-convexa (Hall)				
Pterinea undata Hall				
Pterinea brisa Hall				
Cornulites distans Hall				
[illegible]				
Encrinurus [illegible]				

Dyer Bay Dolomite Lentil.

Description. The Dyer Bay dolomite is typically an impure argillaceous, rather thin-bedded, dolomite lentille in the lower part of the upper half of the Cabot Head shales. Like the Manitoulin dolomite, this dolomitic deposit is a northern representative of shaly deposits farther south. At Dyer bay, the type locality, the section above water consists of 10 feet of thin-bedded, dolomite with blue (green-weathering) sh[illegible] partings. Fossils are numerous and ripple-marks are common. The rock is divided by two sets of vertical joints, with directions about 342 degrees (north 18 degrees west) and 85 degrees (north 85 degrees east). About 17 feet of similar dolomite occurs in the section at the northern extremity of Lion Head cape and partial sections occur on Ba[illegible] H[illegible] bays.

At Cabot head and the "Clay bank" 3 miles to the west, the complete [illegible] exposed. This is 15 feet thick and consists of thin, even-bedded (appearing massive where little weathered), greenish grey, argillaceous dolomite. Characteristic ostracoda occur at the top of the section (see table). About 10 feet of this dolomite connects Centre and West bluffs, at Cabot head, as a ledge or shelf. The bedding is 1 to 3 inches thick and the formation is cut by two sets of vertical joints, with direction 149 degrees (south 31 degrees east) and 281 degrees (west 11 degrees north).

Ten feet of thin-bedded dolomite occurs in the section at the north-eastern extremity of Fitzwilliam island, and in these beds *Virgiana mayvillensis* Savage occurs plentifully, along with *Schuchertella curvistriata* Savage, etc. (see table). From Fitzwilliam north and west, *V. mayvillensis* is common in the Dyer Bay beds, but generally at one definite horizon. At Tamarack cove the dolomite is 15 feet thick, rests upon green shale, and is overlain by firm, green-weathering shale. *V. mayvillensis* and the characteristic ostracoda occur here. On the southeast side of lake Manitou, about 12 feet of Dyer Bay beds occur containing *V. mayvillensis.* The thickest known section of Dyer Bay beds is exposed along the road between West Bay Indian village and Kagawong, just north of a lakelet, on lot 17, concessions VIII and IX, Billings township, Manitoulin island. Here, at least 25 feet of dolomites with some interbedded shale are included in the Dyer Bay beds. A few inches of grey, semicrystalline dolomites occur near the middle, *V. mayvillensis* occurring just below and the Dyer Bay ostracoda 6 or 7 feet higher up. West of Ice Lake on the road to Gore Bay, 5 feet of calcareous shale occurs at the top of 20 feet of red shale containing some firm green beds. In the upper 5 feet of shale, the Dyer Bay ostracoda occur at the top and *V. mayvillensis* occurs near the base.

The Dyer Bay beds are well developed and extend as ledges considerable distances from the base of the Lockport dolomite between the west side of lake Manitou and the western end of Manitoulin island, and also on Cockburn island. Typical outcrops occur on the north end of the island in Mindemoya lake, on the west side of Kagawong lake, near West bay and Ice Lake as mentioned, at the west side of Campbell bay and at Pitman point, Cockburn island. These outcrops almost invariably contain *V. mayvillensis* which was thought throughout the field work to be a small form of *P. oblongus* marking the base of the Lockport formation as the typical *P. oblongus* fills the basal beds of the Lockport dolomite at Owen Sound, Dyer bay, etc. As a consequence the Dyer Bay dolomite was mapped with the Lockport. This error has been corrected so far as could be done in the office. The true Cataract age of the Dyer Bay beds is indicated by Bassler's determination of the ostracoda and by the identification of Alexandrian fossils in the beds on Fitzwilliam island.

Southward from Colpoy bay, the typical Dyer Bay beds are absent, but 2 or 3 feet of ferruginous limestone occurs a little above the centre of the Cabot Head shale as far south as Kelso. This has been termed the "iron band" and contains common Cataract fossils, among others being *Rhynchonella? janea* which also occurs in the Dyer Bay dolomite. It seems probable that this is the southern representative of the Dyer Bay dolomite of the north (for the chemical composition of the iron band at Limehouse, see table page 111).

The recognized fauna of the Dyer Bay dolomite, as shown in the accompanying table, includes one species of plants, five of corals, nine of brachiopods, one of pelecypods, four of ostracods, and one of trilobites. Of these, two brachiopods and three ostracods are new species found only in the Dyer Bay dolomite (see Plate VII).

Fauna of the Dyer Bay Dolomite.

Genera and species.	Barrow Bay	Dyer bay.	Cabot head.	Fitzwilliam island.	Tamarack cove.	South bay.	West bay.	Ice Lake.	Helen bay.	Cockburn island.
Plants.										
Buthotrephis gracilis Hall			x							
Anthozoa.										
Enterolasma cf geometricum (Foerste)				x						
Streptelasma cf hoskinsoni Foerste		x	x							
Syringopora retiformis Billings			x							
Favosites cristatus Edwards and Haime	x	x	x							
Favosites obliquus Rominger		x	x				x			
Brachiopoda.										
Strophonella striata (Hall)			x		x					
Schuchertella curvistriata Savage				x						
Platystrophia biforata (Schlotheim				x						
Virgiana mayvillensis Savage				x	x	x	x	x	x	x
Rhynchotreta thebesensis multistriata Savage				x						
Rhynchotreta cabotensis Williams n. sp			x							
Rhynchonella? janea Billings.	x		x				x			
Rhynchonella? bidens Hall	x									
Homœospira cf immatura Savage				x						
Pelecypoda.										
Pterinea cf undata (Hall)			x							
Ostracoda.										
Leperditia cabotensis Ulrich and Bassler			x		x					
Chilobolbina punctata Ulrich and Bassler			x							
Zygobolbina williamsi Ulrich and Bassler.			x		x			x		
Trilobita.										
Calymene cf clintoni (Vanuxem)	x									

St. Edmund Dolomite Lentille.

Description. A bed of fine-grained, light buff-weathering dolomite occurs near the top of the Cabot Head shale division of the Cataract formation in the vicinity of Dyer bay and Cabot head. At the type locality along the shore 3 miles west of Cabot head, on lots 3 and 4, concession XIV, St. Edmund township, Bruce peninsula, the dolomite is 8 feet thick and tends to be massive. *Favosites cristatus*, a beautiful branching coral, is its characteristic fossil and *Atrypa parksi* occurs rarely. Four feet of soft green shale intervenes between the top of the St. Edmund and the base of the Lockport dolomite, which is thin-bedded as exposed at Cabot head. The character of the St. Edmund at Cabot head is the same as at the type locality. At Dyer bay, the St. Edmund is poorly exposed, but is represented by slabs full of *Favosites cristatus*. The thickness appears to be less at Dyer bay, however, as is also the thickness of the thin beds at the base of the Lockport, judging from the covered interval. Southward on Bruce peninsula, the horizon of the St. Edmund dolomite is generall talus covered. On Manitoulin island this dolomite has not been recognize and appears to be absent.

Microscopic Characters. Examined under the microscope, a specime of St. Edmund dolomite from the Clay cliff near Cabot head proves to l made up of an aggregate of small, uniform, rounded grains of dolomit with an average diameter of 0·01 mm.

A specimen of ferruginous sandy dolomite from near the top of th Cabot Head shale, at Limehouse, under the microscope proves to be com posed of rounded, worn dolomite grains from 0·09 to 0·22 mm. in diamete with a little ferruginous matter. The smaller dolomite grains interloc and show no signs of wear. Numerous sections of bryozoa are present.

Fauna of St. Edmund Dolomite. This is recognized only at the ex posures in the vicinity of Cabot head, where it contains *Favosites cristat* Edwards and Haime and *Atrypa parksi* Williams, n. sp. (see Plates IV V, and VII).

Origin of Cabot Head Member.

Of the origin of the Cabot Head shales Grabau says[1]: "Westwar however, the northern series of deposits (the Upper Juniata) were washe into the sea, the shore of which during Medina time did not probabl extend much farther east than Rochester. In western Ontario, encroach ment of the sea began earlier, for here we have the marine Keppel (Man toulin, author) dolomite resting on a surface of Queenston. Thes dolomites were probably formed while erosion was beginning in the ea and while the early Medina sands were spread by the streams over the ol Ordovicic land surface. Then as the product of this erosion was carri farther westward by repeated reworking, it finally entered the sea, whic had then advanced farther east. Thus the fossiliferous Medina beds western New York and the red and green Cabots Head sands which re on the Keppel dolomite were deposited."

The lack of sandstone in the north is doubtless due to the distan from the shore and the source of the sedimentary materials. The fac however, that in the north the lower beds are red and in the south tl upper beds are red is not easily explained on Grabau's hypothesis alon particularly as there appears to have been continuous deposition of o kind or another throughout the region. However, highly oxidized sed ments on being washed out to sea met deoxidizing agents in the form plant and animal organisms, and it is clear that normal marine conditio extended farther eastward into New York during early Cabot Head tin than during late Cabot Head and Grimsby time. Thus, in the Niaga peninsula the lower Cabot Head, and the underlying Manitoulin be clearly represent marine conditions and the colour is grey; higher be are sandy, representing shallower water, and red is the predominati colour. Grabau derives the sediments forming these deposits from tl older, highly oxidized formations such as the Juniata-Bays. In tl Georgian Bay region, however, it is hardly probable that the origin of tl sediments is as simple as supposed by Grabau. The author has show that in the Lake Timiskaming region, a long period of erosion laid bare early Trenton fossils resting in an irregular basal conglomerate on the Pre-Cambrian rocks, and upon these deposits Niagara limestones were laid down. Elsewhere in the same region, as shown by G. S. Hume,[1] 70 feet of strata lie between the top of the Trenton and the base of the Niagara. Thus a considerable amount of erosion is shown to have occurred in the north during the period including the deposition of the Cabot Head shales. That some of the eroded material should be carried southward is altogether probable and the mingling of the materials eroded from the Richmond shales with the materials coming from the Adirondacks and the nearby crystalline rocks, together with the deoxidizing influence of marine conditions, may easily account for the grey colour of the upper part of the Cabot Head shales. The red colour of the lower Cabot Head shales of the Georgian Bay region may be due to the inwashing of highly oxidized sediments from the nearby Pre-Cambrian areas to the east and north during the predominance of littoral conditions. The probability of sediments coming from these nearby sources cannot be ignored.

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[1] Bull. Geol. Soc. of Am., vol. XXIV, No. 3, Sept., 1913, p. 460.

[2] Geol. Surv., Can., Mus. Bull. 17, p. 6.

The St. Edmund dolomite (a magnesian calcilutite) shows evidence of being composed of dolomite flour and may with the Dyer Bay dolomite have been derived from older dolomites of the northern realm.

GRIMSBY SANDSTONE MEMBER.

Characteristics and Distribution.

The 50 feet of red and grey shale and sandstone at Niagara river, limited below by the Cabot Head shale and above by the Thorold sandstone, has been named by the author the Grimsby[2] member. At Grimsby, the type section consists of 12 feet of thick-bedded, mottled, red and grey sandstone, and 6 feet of grey shale which lies immediately beneath the Thorold sandstone. The underlying strata are red Cabot Head shales.

The Grimsby sandstones show considerable variation, some beds, particularly in the lower half, being decidedly shaly. Crossbedding is common in the thicker beds and lenses and pillow structure are fairly common. The pillow structure appears to the writer to be due to the rolling by current action of masses of sand over thin beds of mud, the incoming sand preserving the form. Current action was certainly present as shown by crossbedding.

The Grimsby sandstone is seen as far west as Dundas, where it is not easily differentiated from the Cabot Head shales, but is about 14 feet thick. Eastward, it increases in thickness, being as above stated, 50 feet at the American line. In Canada this member rests upon the Cabot Head shale, and is doubtless the inshore equivalent of the upper beds of that shale as seen north of Dundas. As far west as Stoney Creek the Grimsby sandstone is overlain by the Thorold quartzite. Whether the upper grey shales and sandstone at Hamilton are to be included with the Grimsby or the Thorold, it is not easy to decide, but on the evidence of pillow structure which is a well known characteristic of the Grimsby sandstone, the lower beds are referred to that member. It is pro-

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[1] [illegible] Can., Sum. Rept., 1916, p. 190.
[2] [illegible] Can., Sum. Rept., [illegible], p. 184.

able that the upper, thin, grey sandstones and shales are a facies of t
Thorold sandstone.

On the evidence of well borings, 25 feet of sandstones at Port Burw
and 45 feet at Paris are referred to the Grimsby member. About 7 fe
of sandstones and shales are referred to the Grimsby at Dundas, and
Kelso, Grimsby beds are lacking. A well record at Beachville indicat
that the Grimsby sandstone is lacking there, and it is also lacking at Lo
don. The northwestern, underground extension of the Grimsby appe
from the above evidence to be approximately limited by a line dra
from the Niagara escarpment between Dundas and Kelso, southwe
passing to the north of Paris and to the east of Beachville and terminati
at the lake Erie shore perhaps in the vicinity of Port Bruce.

Microscopic Characters.

A specimen of green-grey sandstone, from a bed 9 feet above the b
of the Grimsby member at Niagara river, proves under the microsc
to consist of subangular to rounded quartz grains with an average diame
of about 0·1 mm., some chlorite and kaolin, and a very little calcite.

Origin of Grimsby Sandstone.

As already described, Grabau's hypothesis[1] derives the Medina b
from folded Juniata-Bays and Bald Eagle formations in the Appalach
region. Erosion having cut through the Juniata-Bays red beds, we
next attack the grey Bald Eagle conglomerate. The Grimsby sandst
appears to be an inshore phase of the early erosion of the Bald Ea
The finer sediments were deposited farther out to sea, forming the up
Cabot Head beds, and the coarser materials, mixed with the coarser hig
oxidized materials from the red beds, were deposited in an estuary
along the littoral zone of the sea in what is now the Niagara penin
of Ontario. (For fossils see the following table and Plate VIII.)

Fauna of Grimsby Sandstone.

Genera and species.	Niagara river.	Thorold.	Jordan.	Hamilton.	Waterdown.	Flamborough tp.
Brachiopoda.						
Lingula cuneata Conrad	x	x	x	?		
Lingula clintoni Va[illegible]n				x		
Dalmanella eugeni[illegible] Williams n. sp				x		
Camarotœchia (St[illegible]ynchus) neglecta Hall.	x					
Pelecypoda.						
Pterinea cf undata (Hall	x			x	x	x
Pterinea brisa Hall						
Modiolopsis primigenia (Conrad)..	x²			x		
Modiolopsis orthonota (Conrad)	x²					x
Modiolopsis kelsoensis Williams n. sp						x
Ctenodonta machæriformis (Hall)..						x
Nuculites cf ferrugineum Foerste						
Gastropoda.						
Bucanella trilobata (Conrad)....	x					

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[1] Pt. I, page 469

[2] Reported by Grabau

THOROLD SANDSTONE MEMBER.

Characteristics and Distribution.

The grey sandstone at the top of the Medina in New York, and southern Ontario, formerly known as the "Grey Band", has been called by Grabau[1] the "Thorold quartzite". The sandstone is light grey, thin to thick-bedded, and at Thorold is a true quartzite. Elsewhere, "sandstone" more fittingly describes it. The sandstone is commonly crossbedded and contains at Grimsby and elsewhere *Dædalus archimedes* Ringueberg and *Arthrophycus harlani* Hall.

At Niagara gorge the Thorold sandstone is 7 feet thick; it attains a thickness of about 12 feet near DeCew falls, is 6 feet thick at Stoney Creek, and at Hamilton and northward is not clearly differentiated, if present, from the Grimsby sandstone and shale. At its lower contact the Thorold sandstone is marked by little more than a lithologic change from the Grimsby sandstone below. The top bed of sandstone upon which the Clinton [Reynales (Wolcott)] dolomite rests, is thick and free from calcareous matter. At some localities, however, the Reynales dolomite is arenaceous at the base.

Fauna of Thorold Sandstone.

Genera and species.	Niagara river.	Thorold.	Grimsby.	Dundas
[illegible] *in burrows*				
Dædalus archimedes (Ringueberg			x	x
Arthrophycus alleghaniensis (Harlan	x	x	x	x

Microscopic Characters.

A specimen of Thorold quartzite from Thorold, Ont., examined under the microscope, proves to consist of rounded to sub-angular quartz grains of 0·10 mm. average diameter, closely interlocked. Along their contacts, recrystallization has taken place, and some secondary silica has been deposited.

Underground Extension.

As stated above, the Thorold sandstone extends along the Niagara escarpment as far west as the vicinity of Hamilton. Well records indicate that its extent southward is not great, only red sandstones being mentioned in well logs, excepting at Port Colborne, where thin-bedded, white sandstones occur interbedded with red shales, and at Welland where grey shales are recorded above the red sandstones. It appears fairly clear that the Thorold sandstone does not extend underground much beyond a line drawn from Port Colborne northwest to Hamilton.

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[1] Bull Geol Soc Am, vol XXIV, No. 3, p 460

Origin.

The origin of the Thorold sandstone has been explained by Grabau as the result of the erosion of the Bald Eagle conglomerate, after the Juniata-Bays red beds had been cut through to furnish material for the formation of earlier Medina members. The Thorold as well as the Grimsby sand may, however, have been derived from the crystalline rocks of the Appalachian after the removal of the younger strata.

The origin of the Medina sediments, which are at Niagara river, in ascending order, sandstones, shales, sandy dolomite, shales, and sandstones, must be considered from the standpoint of the relative position of the sea and land as well as from the standpoint of the source of sediments.

A. W. G. Wilson[1] has shown that when the rate of depression of the land is greater than the rate of supply of detritus "there will be a uniform shoreward overlap of the zones of deposition", that is from deep to shallow water, limestones will overlap shales, which in their turn will overlap sandstones and conglomerates. Should the rate of depression of the land, later become less than the rate of supply of detritus, the overlap would be reversed, conglomerates and sandstones overlapping shales and shales overlapping limestones to seaward. Thus with a reversed cycle, limestones would be enclosed in shales, and shales in sandstones in a direction from sea to land. It will be readily seen from the sections of the Medina members that this is exactly the same as in the case of the Medina. In the first part of the cycle of sedimentation, whirlpool sandstone was overlapped landward by shales which comprise the base of the Manitoulin beds in its southern extension, and the shales and sandstones both were overlapped by dolomite. With the reversed order Cabot Head shales overlapped Manitoulin dolomite to seaward, and Grimsby sandstones overlapped the shales in the same direction. The Thorold sandstone and the Oneida conglomerate of New York state may represent a temporary mastery o the depression of the land over the supply of detritus. That is, the shaly character of the upper Grimsby sandstone, followed by the limited deposits of Thorold sandstone, may well indicate a slight advance of the sea at the end of Medina time.

The reason for the change of balance in the factors controlling sedimentation, as applied to Medina sediments, is to be found on the one hand in the relative change in elevation of land and sea, and on the other in the varying sources of supply of sediments as erosion progressed

CORRELATION AND AGE OF THE MEDINA-CATARACT FORMATION

As already stated the Medina is represented in eastern New York state entirely by sandstone and conglomerate. This is because of proximity of the Appalachian mountains which were the main source of the sediments. Bassler[2] correlates the Oneida-Shawangunk-Green Pond formation of central and eastern New York state with the Medina below the Thorold

According to Ulrich[3] the Clinch sandstone of Tennessee is probably the equivalent of the Tuscarora sandstone of Pennsylvania and in genera also the equivalent of the Medina (restricted use) of New York and Ontario

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[1] Can. Rec. of Sc. vol. IX, No. 2, 1903, p. 119

[2] U. S. Nat. Mus., Bull. 92, vol. I and II, 1915, pl. 3

[3] Bull. Geol. Soc. Am. No. 3, vol. XXII, 1911, p. 468

Savage has recently described in detail the stratigraphy and palæontology of the Alexandrian series in Illinois and Missouri.[1] He has divided the series in ascending order[2] into Girardeau limestone, Edgewood limestone, Essex limestone, and Sexton Creek (Brassfield) limestone.

In a later article,[3] Savage indicates important correlations. After referring *Conchidium decussatum* Whiteaves to the genus *Virgiana* recently described by Twenhofel, Savage says in part as follows: "In the Grand Rapids region the layers containing *Virgiana decussata* are succeeded by strata which contain the fossils *Pterinea occidentalis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina*. In the Hudson Bay region a zone a few feet above the horizon of *Virgiana decussata* furnished shells of *Camarotœchia? winiskensis*, *Pterinea occidentalis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina*. In the northern peninsula of Michigan early Silurian strata containing *Camarotœchia? winiskensis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina* overlie the strata containing *Virgiana mayvillensis*, which is a near relative of *Virgiana decussata*. In eastern Wisconsin *Virgiana mayvillensis* occurs in the uppermost layers of the Mayville limestone, above which there is a stratigraphic break, the horizon of *Camarotœchia? winiskensis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina*, present farther east in northern Michigan, having been removed by erosion. However, there is no doubt that the strata which in northern Michigan contain *Virgiana mayvillensis* correspond in age to those containing the same species in the upper part of Mayville limestone in Wisconsin, as they are clearly a northeastward continuation of the same beds"......

"In Wisconsin there was found in the quarry near Pebbles a zone only a few feet below the horizon of *Virgiana mayvillensis* and apparently conformable with it, which yielded such characteristic Edgewood species of fossils as *Dalmanella edgewoodensis*, *Rhynchonella? janea*, *Rhynchotreta parva*, and *Atrypa putilla*. The position of *Virgiana mayvillensis* in Wisconsin in the upper part of the Mayville limestone, which at a slightly lower level contains a characteristic Edgewood fauna, indicates that this horizon is Alexandrian (late Edgewood) in age. It is also significant that the strata containing *Virgiana mayvillensis* in Wisconsin seems to occupy about the same position in the Silurian column as do the strata which contain *Virgiana barrandei* in the Becsie River formation of Anticosti island."

"In Michigan the strata containing *Camarotœchia? winiskensis*, *Isochilina grandis* var. *latimarginata*, and *Leperditia hisingeri* var. *fabulina* conformably overlie the *Virgiana mayvillensis* beds, and thus are thought to correspond in age to about that of the Sexton Creek or Kankakee limestone which overlies the Edgewood in Illinois and Missouri, but they were deposited in a different geologic province."

"The close correspondence in the fauna of the strata overlying the *Virgiana mayvillensis* zone in northern Michigan with that of the strata above the horizon of *Virgiana decussata* in the Hudson Bay and Saskatchewan regions leaves no doubt of the equivalence of the strata containing

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[1] Illinois Geol. Surv., Bull. 23, 1917, pp. 67-160.

[2] [illegible] p. 73.

[3] "Correlation of the early Silurian rocks in the Hudson Bay region," Jour. of Geol., vol. XXVI, 1918, pp. 336-340.

this fauna in the areas above mentioned. They also prove that the *Virgi*
mayvillensis zone in Wisconsin and Michigan, and the *Virgiana decuss*
zone in the Hudson Bay and Saskatchewan localities represent the sa
stratigraphic horizon."

"Besides the above-mentioned localities Hume[1] has found ea
Silurian strata containing *Camarotœchia? winiskensis*, and numer
ostracods in the lake Timiskaming area that he correlates with the Catara
formation, which doubtless corresponds with the *Camarotœchia? winisk*
sis, *Isochilina*, and *Leperditia* horizon in the regions above described."

"Kindle[2] found Silurian strata several hundred miles north of
Grand Rapids locality, in the vicinity of The Pas from which he obtain
the fossils *Camarotœchia? winiskensis*, *Pterinea* cf. *occidentalis*, and *Le*
ditia cf. *hisingeri*. This fauna also indicates a horizon about equival
to that of the Silurian in the lake Timiskaming region and to the stra
containing *Pterinea occidentalis*, *Isochilina*, and *Leperditia*, above
Virgiana decussata horizon in the Grand Rapids section, the latter horiz
not being exposed in the more northern locality. From the similarity
the faunas of the *Virgiana* zone, and of the higher strata containing *Ca*
arotœchia? winiskensis, *Isochilina grandis* var. *latimarginata*, and *Leperdi*
hisingeri var. *fabulina* in the regions above described it is inferred th
during the time those strata were laid down the above-mentioned regio
were a part of the same province or basin of deposition, which w
rather broadly connected northward with the Arctic ocean."

The presence of *Virgiana mayvillensis* in the Dyer Bay dolomite clea
establishes its equivalence with the *Virgiana* zones described by Sava
As the Dyer Bay dolomite which is near the top of the Cataract formati
is of upper Edgewood age, it seems probable that the remainder of the Cab
Head shale and the Manitoulin dolomite are of lower Edgewood age.
the Girardeau and the Manitoulin dolomite have little in common.

The diagnostic species common to the Manitoulin dolomite and
divisions of the Edgewood limestone indicated are:

Rhipidomella hybrida Channahon limestone, Ill
Rhynchonella? janea Edgewood limestone, Ill
Bucania cf *exigua* Edgewood limestone, Ill

The species common to the Manitoulin dolomite and Brassfie
limestone are:

Clathrodictyon vesiculosum Sexton Creek limestone, Ill
Homotrypa? confluens Brassfield limestone, Dayton, Ohio
Pachydictya turgida Brassfield limestone, Dayton and Fair Haven, Ohio
Strophonella striata Brassfield limestone, Ky.
Herbertella fausta Brassfield limestone, Ohio
Rhipidomella hybrida Brassfield limestone, Ky.

The species common to the Dyer Bay dolomite and the Edgew
limestone are:

Schuchertella curvistriata Channahon limestone, Ill.
Rhynchrotreta thebesensis var. *multistriata* Edgewood limestone, Ill.
Rhynchonella? janea Edgewood, Ill. and Mo.

It will be seen that the fossil evidence is not definite enough to ma
close divisional correlations. An anomaly is present in the close relati

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[1] G. S. Hume, "Palæozoic rocks of lake Timiskaming area," Geol. Surv., Can., Sum. Rep., 1916, pp. 18
Fossils reported by Charles Schuchert in a personal letter

[2] E. M. Kindle, op. cit., p. 12

ships of the faunas of the Manitoulin dolomite and the Brassfield limestone, for the Dyer Bay dolomite, which is much higher than the Manitoulin dolomite, is more closely related by its fauna to the Edgewood limestone which underlies the Brassfield limestone.

Schuchert's summary of the relation of the Cataract formation to other formations, written before the completion of the work done by Savage and the author, is given below for comparison. After discussing the relation of the Cataract and Medina faunas, Schuchert adds:

"It should also be stated that the Medina is of the Appalachian province, while the Cataract is either of the St. Lawrence or of the Arctic realm. These waters came in over the continent from different oceanic areas and accordingly have different organic associations. Hence the similarity of the biotas cannot be close, and this, with the marked difference in sedimentation, gives additional reason why considerable weight is laid on the forms held in common, as showing that both formations are the deposits of about one time."

Under "Relation to the Brassfield," Schuchert says: "The Cataract may also be compared with the Brassfield formation of Ohio and Indiana, as the two are clearly related, and also as both are of a limestone facies. Between the two there are twenty-four forms in common, and of these the following have the most significance in correlation. *Clathrodictyon vesiculosum*, *Acervularia* (?) *gracilis* (in Ohio, *A. clintonensis*), *Rhinopora verrucosa*, *Phaenopora ensiformis*, *Callopora magnopora*, *Homotrypa* (?) *confluens*, and *Hebertella fausta*."

Under "Relation to the Siluric of Anticosti," Schuchert says: "The Cataract does not readily correlate with the Anticosti section because of the marked differences and generalized character of the faunas there, and more especially because of the long range of most of the species. With the Becsie River, the only guide fossil in common is *Camarotoechia planoconvexa* (appearing about 70 feet above the base of the Becsie River); but the Anticosti individuals are only half grown compared with those of the Cataract, a condition seemingly in harmony with the conclusion that the latter are of a younger time. Then the absence in the Cataract of the Becsie River guide, *Clorinda barrandei*, also seems to indicate that the former formation is of younger age. At the top of the Becsie River, however, the fauna is more like that of the Cataract, and this similarity continues in the succeeding 300 feet of the Gun River formation."

Schuchert[2] says "Even though the Medina, Cataract, and Brassfield are correlates of one another, it does not follow that each one is wholly the equivalent of any other. Each formation invades eastern North America from a different direction and each one has its own peculiar faunal assemblage. They, therefore, represent three physical provinces and marine basins. The Medina is of the northern Appalachian province, is a sandstone formation, and finally invades to a slight extent the area of the Cataract. The Brassfield province lies, in the main, west of the Cincinnati axis, is of southern origin, with limestone-making seas, spreading up the southern portion of the Appalachian province, and finally invades slightly the area of the Cataract sea. On the other hand, the Cataract province spreads westward through the Saint Lawrence embayment, and finally, in eastern Ontario and northeastern Ohio (kn from the Clinton oil wells), unites with the other two provinces; bu the Medina waters form a shoal sandy area in northeastern Ohio betw the other two provinces very few of the species of either area intermigr Probably it would be more correct to state that the normal marine junc of the Cataract and Brassfield seas is prevented by the Medina de For these reasons Medina, Cataract, and Brassfield are to be retaine names for independent marine faunas and formations."

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[2] Geol. Soc. Am., vol. XXV, [illegible]
[illegible] 294

According to Twenhofel[1] the Cataract formation is probably t correlated with the lower portion of the Gun River formation of Antic island. No sediments in the Silurian section at Arisaig have been identi as being as old as the Medina-Cataract, although it is possible that base of the Beechhill Cove formation may be of this age.

Bassler correlates the Medina-Cataract with the Lower Llando of Wales and Shropshire and the Lower Birkhill of Scotland.

CLINTON FORMATION.

As here described the Clinton formation includes the shales limestones between the Medina-Cataract formation below and the Roc ter[2] formation above.

DEFINITION AND GENERAL DESCRIPTION.

As already stated, the Manitoulin dolomite of Ontario, along the overlying shales, were by Sir William Logan misnamed the Cli formation. This was partly due to the mistaken idea that the Whirl sandstone of Ontario was the "Grey band" of New York, and pa because the Manitoulin dolomite was a convenient horizon-marker. quote Logan[3], "In Canada, for reasons which will be stated in descri the Niagara formation, it is found convenient to limit the Clinton to strata beneath the Pentamerus band, and to include this band in Niagara formation. On the Niagara river, the Clinton is thus lim to a few feet, but it gradually augments to the northward". And u "Niagara Formation" Logan[4] says: "We therefore, propose to includ the Niagara series, the two bands of limestone which underlie the sh and which, in New York, constitute the upper part of the Clinton for tion. So far as they have been examined in Canada, these two l stone bands contain no Clinton fossils, but such as pass upwards into Niagara; and the upper band here possesses one or two species, wh in New York, are considered to belong to the latter group only. T would thus appear, at present, to be no palæontological reason why t limestones may not be considered the base of the Niagara format while geographically they present a very marked feature for a considerable distance, and afford a convenient means of describing the distribution of the two formations."

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[1] Geol. Surv., Can., Mus. Bull. 3, 1914, p. 20.

[2] It is now the custom of the United States Geological Survey and the New York State Survey to inclu Rochester shale in the Clinton formation, on the ground that the Rochester shale is included in the Clinton se Clinton, New York. In the opinion of the Canadian Geological Survey, this contention is not proved. other hand, in western New York and in Ontario, the Rochester was clearly considered a part of the Niaga mation by Hall, Logan, and other early workers in the region. There is no denying the continuity of sedimen and faunal development from the Irondequoit to the Rochester, and according to Chadwick, what has considered by the author only an apparent break, at the top of the Rochester, is due to disconformity and A number of fossils, however, are common to the Rochester and the Lockport and for the present the ol the term Clinton is maintained by the Geological Survey, Canada.

[3] Geology of Canada, 1863, p. 312.

[4] Ibid, page 322.

Admitting the close relationship between the Clinton and Niagara formations, it is nevertheless impossible to ignore the distinct characters both palæontologic and stratigraphic of the Clinton formation, even in its vanishing condition near Hamilton.

Only the upper part of the Clinton of New York is present in Ontario. Thus of the seven divisions recognized by Chadwick[1] at Rochester, only three occur with certainty at Niagara, and a fourth is doubtfully recognized. The divisions at Rochester are from the base up: Maplewood (Sodus) shale; Bear Creek limestone and shale; Furnaceville iron ore and limestone; Reynales (Wolcott) limestone; Sodus and Williamson (Williamson) shales; and Irondequoit limestone. At Niagara river, a shale probably of the age of a part of the Furnaceville beds (formerly called the Sodus shale), the Reynales (Wolcott) dolomite, and the Irondequoit dolomite are well represented and the Williamson shale is suggested by the shaly parting between the Reynales and Irondequoit. The total thickness of the Clinton at Rochester is about 80 feet, and at Niagara river 23 feet. Hall called the Clinton the Protean group because of its varied character, shale being dominant in eastern New York, and shale and calcareous beds being about equally represented in western New York. The variation between Rochester and Niagara river is indicative of the protean character of the Clinton and the changes are striking from place to place in Ontario. The Clinton outcrops at many places along the Niagara escarpment between Niagara river and Kelso.

The Furnaceville shale is not seen west of Niagara river, unless a few inches of shale at DeCew falls represents it. The Irondequoit dolomite thins out to the westward, being last seen along with the overlying Rochester shale near Waterdown. The Reynales dolomite is 6 feet thick at Kelso and contains *Pentamerus oblongus* near the base, just as at Thorold and other more eastern localities, but it has not been identified farther west or north. A similar bed at Limehouse contains *Dictyonema retiforme*, and probably represents the horizon of the DeCew water-lime rather than the Reynales dolomite. Well records indicate that Clinton dolomite extends westward beneath younger formations as far as lake St. Clair where about 5 feet of limestone occurs at the base of the Rochester shale. Samples of drillings from a well on lot 1, concession V, Bayham township, Elgin county, and from another at Beachville, Oxford county, indicate 20 feet or more of dolomite at the Clinton horizon. For the distribution of the Clinton, see Maps 1714 and 1715. For fossils see tables under description of members and Plates IX and X.

THE FURNACEVILLE (SODUS) SHALE MEMBER.

Description.

The Furnaceville (Sodus) or lowest division of the Clinton at Niagara gorge is a soft, fissile, bluish-grey shale weathering greenish. It rests

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[1] The nomenclature and correlation of the Clinton formation of New York state has been recently revised by Chadwick. His nomenclature is here followed. The terminology formerly recognized is placed in brackets.

[illegible] and sharply on the Thorold sandstone, with no indication of tran[illegible]tion beds. The best outcrops are along the New York Central and Hud River railway between Niagara Falls and Lewiston and about seve [illegible] of a mile north of Niagara university; here, the shale is 4 [illegible] thick. A few inches of green shale occupies the position of the Furnace [illegible] at DeCew falls but is unknown elsewhere in Ontario. The accompan [illegible] table gives the Furnaceville fossils found on the Niagara river.

The Furnaceville (Sodus) Shale Fauna of the Niagara River[1]

[illegible] Hall (G)
[illegible] Hall
[illegible] Sow[illegible] (G)
Pterinea emacerata Conrad
Ctenodonta elliptica (Hall)
[illegible] Whitfield and Hovey
Orthoceras sp.[2]

Of the above, *Calospira hemisphærica*, according to Chadwick, [illegible] found only in the Furnaceville and Sodus divisions.

THE REYNALES (WOLCOTT) DOLOMITE MEMBER.

Description.

The Reynales division of the Clinton is a dark grey, fine-graine [illegible] ic limestone, approaching a true dolomite in composition (se chemical analysis, page 111). It rests with sharp even contact on th Furnaceville shale at Niagara gorge, forms the basal Clinton membe along the Niagara escarpment between Thorold and Waterdown, and the only representative of the Clinton from the vicinity of Waterdown t Kelso, beyond which it has not been identified. West of Niagara rive the Reynales dolomite rests successively on Thorold sandstone and Cabo Head shale. The contact is everywhere sharp, but the basal dolo [illegible] arenaceous at some localities.

Good exposures [illegible] occur along the New York Centr and Hudson River rail[illegible] Niagara Falls and Lewiston, fr one-half to seven-eighths [illegible] north of Niagara university; at Niaga Glen on the Ontario [illegible]; and at numerous localities alo the Niagara escarpment [illegible]. Some of the best localities f study are at DeCew [illegible] Stoney Creek, Hamilton, Dunda and Kelso. At Niagara [illegible] Reynales is 12 feet thick and weath into thin beds. Westw[illegible] and is commonly thick-bedd At Jordan, 3 feet of shale [illegible] near the middle of this division.

Guide Fossils.

Hyattidina congesta and *Stricklandinia canadensis* are guide fos to the Reynales dolomite. *Pentamerus oblongus*, formerly considere guide fossil for New York state, is shown by Chadwick to occur

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[1] Those reported by Grabau are marked (G).
[2] Chadwick identifies this as Cycloceras nitens Vanuxem.

[illegible] the W[illegible] limestone used [illegible] *P. oblongus* has not been reported. As will be seen on page 1[illegible]9 however *Pentamerus oblongus* has a wide range. The other Reynales fossils with the distribution [illegible] work [illegible] out by the [illegible] given [illegible]

Distribution of the Reynales [illegible] Fauna in Ontario.

Genera and species	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] gracilis Hall	x						
[illegible]							
Zaphrentis turbinata Hall		[illegible]					
Favosites niagarensis Hall						[illegible]	
[illegible]							
Lichenalia concentrica Hall	xg						
[illegible]							
Stropheodonta profunda Hall	g						
Strophonella patenta Hall	g						
Plectambonites transversalis (Wahlenberg)		x					
Schuchertella subplana (Hall)		x					
Platystrophia biforata (Schlotheim)	x						
Stricklandinia canadensis (Billings)				x	x		
Pentamerus oblongus Sowerby		x	x	x	x		x
Camarotoechia (Stegerhynchus) neglecta Hall	xg						
Spirifer radiatus Sowerby		x					
Hyattidina congesta (Conrad)	xg						
Coelospira plicatula Hall	g						
[illegible]							
Diaphorostoma niagarense (Hall)		x					
[illegible]							
[illegible]tinoceras vertebratum Hall				x			

[illegible] Hall and Whitfield.

[illegible] Reported by [illegible]
[illegible] found by the [illegible]

WILLIAMSON SHALE MEMBER.

Description.

The Williamson shale is an important member of the Clinton [illegible] at Rochester, having a thickness along with the underlying Sodus [illegible] about 24 feet. At Niagara gorge, Grabau and Kindle [illegible] that this shale is entirely absent. There is, however, at the contact between the Reynales and the Irondequoit dolomites, about 1 inch of grey shaly weathering rock that suggests the attenuated [illegible]

[illegible] challenges this statement, stating that he has always considered the Clinton [illegible] Lockport. The author has been unable to find distinctive characters, although the pro[illegible]

of the Williamson. At DeCew falls, 4 inches of definitely defined, da
grey shale separates the Reynales and Irondequoit dolomites. It
probable that this is the western remnant of the Williamson shale.
fossils have been found in it.

IRONDEQUOIT DOLOMITE MEMBER.

Description.

The Irondequoit member of the Clinton is a light grey or buff, cr
talline, dolomitic limestone, approaching a true dolomite in compositi
(see chemical analysis, page 111). At Niagara gorge, reef structur
consisting of lenses of dense, amorphous dolomite 6 to 35 feet across a
as much as 10 feet thick, are common in the upper part of the Irondequ
dolomite and in places extend upward into the overlying Rochester sha
These reefs are composed mostly of undetermined bryozoan remains a
contain as well a rich brachiopod fauna which includes numerous spe
common in the Rochester. Free swimming animals, such as the trilobit
also frequented the openings in the reefs. Corals were practically abse
with the exception of the little cup coral, *Enterolasma caliculus.* *Lichena*
concentrica is the one identified species of bryozoa present.

The lower contact of the Irondequoit, whether with the Williams
shale or the Reynales dolomite, is generally sharp and clear-cut.
one quarry in Waterdown, however, the base of the Irondequoit is cemen
to the top of the Reynales. The Irondequoit is well exposed along w
the Reynales dolomite as far west as Waterdown. At the Niagara go
it is 7 feet thick and consists of a 1-foot bed at the base and an up
massive 6-foot bed. At Waterdown the section consists of a basal
of argillaceous dolomite 1 foot thick and an upper bed of crinoidal dolom
3½ feet thick. Northward the Irondequoit has not been reported a
it is known to be absent at Kelso.

Because of its thick bedding and toughness the Irondequoit is kno
to the quarrymen of the Hamilton area as the "Nigger Head" bed
is commonly left as a quarry floor.

The Irondequoit fauna is closely related to the fauna of the overly
Rochester shale and the reef structures represent transitional conditio
The fauna with its distribution is shown in the following table.

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[1] Kindle, E. M., U. S. Geol. Surv., Niagara Folio, No. 190, p. 7

Distribution of Irondequoit Fauna in Ontario.

Genera and species	Niagara river		DeCew falls
	Bedded formation	Reefs	Bedded formation
Anthozoa			
Enterolasma caliculum (Hall)	g		
Crinoidea.			
Glyptocrinus plumosus (Hall)	g		
Eucalyptocrinus caelatus levis (Grabau and Shimer)		g	
Bryozoa			
Lichenalia concentrica Hall		g	
Brachiopoda.			
Leptaena rhomboidalis (Wilckens)	xg	g	x
Stropheodonta profunda (Hall)	g		x
Strophonella? patenta (Hall)	xg	g	x
Plectambonites transversalis (Wahlenberg)		g	
Schuchertella subplana (Hall)	xg	g	
Orthis flabellites Foerste	g		
Dalmanella elegantula (Dalman)	x	g*	x
Rhipidomella hybrida (Sowerby)			x
Anastrophia interplicata (Hall)		g	
[1]Pentamerus oblongus Sowerby	g		
Clorinda fornicata (Hall)	xg		
Rhynchotreta cuneata americana (Hall)		g	
Rhynchotreta robusta (Hall)	x		
Camarotoechia (Stegerhynchus) neglecta (Hall)		g	
Camarotoechia? acinus (Hall)	g		
Atrypa reticularis (Linnaeus)	xg	g	x
Atrypa nodostriata Hall	x	g	
Atrypa rugosa Hall		g	
Spirifer radiatus (Sowerby)	xg	g	x
Spirifer niagarensis (Conrad)	xg	g	x
Spirifer crispus (Hisinger)		g	
Spirifer corallinensis (Grabau)	g		
Spirifer (Delthyris) sulcatus (Hisinger)		g	
Whitfieldella nitida (Hall)		g	
Whitfieldella nitida oblata (Hall)	xg	g	x
Whitfieldella (Intermedia) (Hall)		g	x
Whitfieldella cylindrica (Hall)	xg		x
Pelecypoda			
Pterinea brisa Hall			Hamilton?
Gastropoda			
Diaphorostoma niagarense (Hall)		g	
Cephalopoda.			
Dawsonoceras americanum (Foord)			x
Trilobita			
Bumastis ioxus (Hall)	g	g	
Calymene niagarensis Hall	g		

[1] Grabau reports one specimen from the Niagara gorge.

Of the above, Rhynchotreta robusta (Hall), may be taken as a fair guide fossil to the [illegible]

* Found also in the Rochester shale.

g Reported by Grabau.

x Found by author.

CORRELATION OF CLINTON MEMBERS.

The [illegible]t correlation of the Clinton formation of Ontario with t [illegible] New Y[illegible] state is evident from the terminology and descriptions give above. According to Bassler[1], who made use of the latest reports i his work, it is correlated with other formations as follows (the autho however, has eliminated formations correlated with the Rochester whic is included in the Clinton by Bassler): with the Clinton group of Penn sylvania, Maryland, and Virginia including the Cacapon member at th base and the Keefer sandstone near the top; the Dayton limestone an "Niagara" shale of Ohio; the Crab Orchard formation of eastern Ke tucky; the middle part of the St. Clair limestone of northern Arkansa the St. Clair limestone of central Oklahoma; the upper part of the Gu River, the Jupiter River (= Williamson and Irondequoit), and a pa of the Chicotte (= Irondequoit Rochester) formation of Anticosti[2] islan the Beechhill Cove and Ross Brook formations of Arisaig; and the Upp Llandovery and Tarannon of Wales and Shropshire and the Upper Birkh and Tarannon of Scotland.

In the light of the recent revisions of the Clinton formation, Schuche informs the author that he still connects the Clinton sea of New Yo and Ontario with the gulf of Mexico, as in his "Paleogeography of Nor America."[3] There was a land barrier in eastern North America whi separated the equivalent seas of the gulf of St. Lawrence and the Ne York-Ontario areas. The deposits of New York-Ontario are those an oscillating sea in which the adjustments of elastic to calcareous sed ments were nicely balanced.

NIAGARA GROUP.

Definition and Use of Terms.

The Niagara group[4] as defined in this report includes the Roch (Niagara) shale and the Lockport (Niagara) dolomite, or in other wo the strata between the Clinton dolomite and, where this is lacking, Cataract formation below and the Guelph formation above.

The Rochester is the more important member of the Niaga central New York, but thins out westward, and in Ontario is contin in outcrop to the Niagara peninsula. The Lockport dolomite is el defined at Rochester and westward and northward it is of increasing thickness, being the great cliff-forming dolomite of the Niagara escarpment.

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[1] [illegible] Nat. Mus. Bull. 92, vol. II, 1915, pls. 3 and 4.

[2] Geol. Surv., Can., Mus. Bull. 3, 1914, pp. 20 and 21.

[3] [illegible] N. A. 1909, p. 565.

[4] [illegible] of Logan, who used "formation," "series," or "group" without distinction [illegible] Canadian geologists, who followed the terminology of the New York State survey [illegible] Lockport dolomite. As will be described under the [illegible] there is an appa[illegible] Rochester, but the author has seen little [illegible] Lockport time. Chadwick, however, [illegible] evidence in New Y[illegible] [illegible] conformity at the top of the Rochester. [illegible] the Clinton and recently emphasized by Chadwick, the Irondequoit and Rochester [illegible] eventually be placed in a formation by themselves. [illegible] Lockport. On the other hand, to place the closely related Irondequoit [illegible] [illegible] preferable to including the Rochester with the Clinton formation [illegible] both it and the Irondequoit differ materially. Until a [illegible]

It is this Lockport dolomite and its equivalents under other names which have made the Niagara the best known of all the Silurian formations in the regions of the Great Lakes, lake Timiskaming, lake Winnipeg, Hudson bay, and the Arctic.

ROCHESTER SHALE FORMATION.

Description.

The Rochester shale takes its name from the type section at Rochester, where according to Kindle[1] it is 85 feet thick. This, formerly known as the Niagara shale, consists of fissile, dark grey shale, containing calcareous beds. The harder or more calcareous beds generally occur near the top but at Niagara falls they are most common near the middle and in the lower half of the shale.

The Rochester shale, as stated above, is closely related to the Irondequoit dolomite upon which it rests and along with which it thins out to the north of Waterdown. The contact is a gradation from shaly dolomite to shale and at Niagara river amorphous reefs project upward from the Irondequoit into the Rochester. The fauna is likewise transitional, the species of the upper shaly Irondequoit beds and of the reefs, being commoner in the Rochester than in the Irondequoit below.

The fauna of the Rochester shale is rich in genera and species, and with the exception of the *Eurypterida* has all the main Silurian classes of marine organisms, well represented. The greatest profusion of species, however, is to be found among the brachiopods, bryozoa, and trilobites. For the fauna and its distribution, see the accompanying table and Plates X, XII, and XIII.

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[1] See Niagara Folio No. 190, p. 7.

Distribution of Rochester Fauna in Ontario.

Genera and species.	Niagara river		Thorold		DeCew Falls	Grimsby			Hamilton	[illegible]
	Lower.	Upper.	Lower	Upper	Upper	Lower	Upper	Loose		
Plantae.										
Buthotrephis gracilis Hall			x							
Hydrozoa.										
Dictyonema retiforme Hall	g		x							
Dictyonema gracile Hall						x				
Anthozoa.										
Enterolasma caliculum Hall	Ng		x	x		x	x			
Zaphrentis turbinata Hall	N									
Favosites hisingeri Edwards and Haime	g							x		
Favosites niagarensis Hall	N					x				
Cladopora seriata Hall	g									
Striatopora flexuosa Hall	g									
Cystoidea.										
Caryocrinites ornatus Say	Ng		x			x	x	x		
Crinoidea.										
Stephanocrinus angulatus Conrad	Ng						x	x		
Eucalyptocrinus coelatus laevis Grabau and Shimer	g							x		
Ichthyocrinus laevis Conrad	g									
Annelida.										
Cornulites bellistriatus Hall	g'							x		
Bryozoa.										
Chilotrypa ostiolata Hall	g									
Batostomella granulifera Hall	g		.			b			b	
Nicholsonella florida Hall	g									
Trematopora tuberculosa Hall	g		b			b				
Hallopora elegantula Hall	g		b		.	b			b	
Chasmatopora asperatostriata Hall	g		b			b			b	
Pseudohornera diffusa Hall	g					b				
Fenestella elegans Hall	g		b			b			b	
Semicoscinium tenuiceps Hall	g					b				
Polypora incepta Hall	g					b				
Clathropora alcicornis Hall	g									
Diamesopora dichotoma Hall	g					b			b	
Lichenalia concentrica Hall	Ng				. .	b	x			

[illegible]					x					
[illegible] Hall¹					x					
[illegible] Hall	g									
[illegible] Hall	g									
Leptaena rhomboidalis Wilckens	xg	g	x	x	x	x	x	x		
Strophonella striata Hall	xg	g			x					
Strophonella? patenta (Hall)	xg?		?	?			x	x		x
Strophonella? decewensis Williams					x					
Plectambonites transversalis (Wahlenberg)	xg					x	x	x		
Schuchertella subplana (Hall)	g	g			x		x	x		x
Orthis flabellites Foerste	g							x		
Schizophoria punctostriata Hall	xg?									
Orthostrophia (Schizogramma) fasciata Hall	?							x		
Dalmanella elegantula (Dalman)	xg					x	x	x		
Rhipidomella hybrida (Sowerby)	xg	g		x		x	x	x		
Anastrophia interplicata (Hall)	g									
Rhynchotreta cuneata americana Hall	xg	g			x					
Rhynchotreta robusta Hall	x									
Camarotoechia obtusiplicata Hall	xg					x	x	x		
Camarotoechia (Stegerhynchus) neglecta (Hall)	xg	g		x	x			x		
Atrypa reticularis (Linnaeus)	xg				x		x	x		
Atrypa nodostriata Hall	xg								?	
Atrypa rugosa Hall	g									
Spirifer radiatus (Sowerby)	xg		x				x	x		
Spirifer niagarensis (Conrad)	xg		x		x	x	x	x		
Spirifer crispus (Hisinger)	xg		x					x		
Spirifer corallinensis Grabau	g									
Spirifer (Delthyris) sulcatus Hisinger	g									
Trematospira camura Hall	g									
Whitfieldella nitida Hall	g				x					
Whitfieldella nitida oblata Hall	xg	x				x	x	x		
Whitfieldella intermedia Hall	xg									
Whitfieldella cylindrica Hall	xg								x	x
Pelecypoda.										
Pterinea emacerata (Conrad	g	xg			x					
Pterinea undata Hall					x					
Leiopteria subplana Hall	g									
Gastropoda.										
²Platyceras angulatum Hall	xg				x					
Diaphorostoma niagarense Hall	xg	g					x	x		
Diaphorostoma hemisphericum Hall						x				
[illegible]										
Tentaculites niagarensis Hall	x									
Tentaculites minutus Hall	x									

¹Found only [illegible]

²Found only [illegible]

Distribution of Rochester Fauna in Ontario—Concluded.

Genera and species	Niagara river		Thorold		Decew Falls[1]	Grimsby			Hamilton	Waterdown
	Lower.	Upper.	Lower	Upper	Upper	Lower	Upper	Lower		
Cephalopoda.										
Orthoceras unionense Worthen					x					
Kionoceras cancellatum (Hall)										
Ostracoda.										
Aechmina spinosa (Hall)	xg[2]	x								
Trilobita.										
[2]Homalonotus delphinocephalus (Green)	g	g		x	x					
Bumastus ioxus (Hall)	xg					x	x			
[2]Dalmanites limulurus (Green)	xg	xg			x			x		x
Calymene niagarensis Hall	g									
[1]Arctinurus boltoni (Bigsby)	g									
Encrinurus ornatus Hall and Whitfield						x				

NOTE. Fossils listed by Grabau are marked "g," those found by the author are marked "x," those reported by [illegible] are marked "b." Bassler does not note the horizon at which found.

[1] Found only in the Rochester shale.

[2] Good guides to the Rochester.

LOCKPORT DOLOMITE FORMATION.[1]

General Description.

The Lockport dolomite is named from the type section at Lockport, New York, where the section consists "chiefly of dark grey to chocolate coloured dolomite".[2] Two horizons of Guelph fossils known as the lower and upper Shelby have been found in New York with an intervening zone of Lockport fossils. This has led to considerable confusion, but Chadwick and the author have identified the Eramosa beds (at the top of the Lockport) at Niagara river and at Rochester, thus showing that the Guelph formation is well defined in New York state and includes the beds (so far as identifications have been made) from the base of the upper Shelby up. At Niagara river the crest of the American falls is at the top of the Eramosa beds which are also exposed along the Gorge route below the power-house on the New York side. They are about 12 feet thick and comprise Clarke and Ruedemann's division 4,[3] which contains a "continuous bed of chert nodules near the top", thought to be the "probable horizon of the upper Shelby fauna." Although the fossil occurrences do not exactly coincide, the conditions are similar to those described below for the Eramosa beds near the city of Guelph, where some Guelph forms occur in coral reefs at the base of the Eramosa beds and the true Guelph fauna comes in just above them. The transitional nature of the Eramosa beds is clear, and so Guelph species may be found at different horizons, but the Guelph formation in Ontario is clearly defined as a stratigraphic unit and is continuous with the New York formation above the Eramosa beds which are now recognized east of Niagara river.

The propriety of extending the use of the name Lockport over Ontario is supported by the continuity of the formation, the decided gradation where changes occur, and the marked faunal elements common throughout the formation. Of the one hundred and thirty-five species listed by the author for the Niagara dolomite of Ontario, twenty-five occur in the Lockport of New York state, and forty-eight occur in the Lockport at Thorold, only 8 miles from Niagara Falls. The northern coral development exemplified by occurrences at Cabot head and Fossil hill is quite different from the fauna of the more argillaceous dolomite at Lockport, New York, but important species are in common and it is well recognized that corals develop under special conditions and with special associates. The relationship of this coral fauna to the Louisville fauna is well marked, but the fact that the Guelph formation overlies the coral horizons of Bruce peninsula strengthens the conclusion arrived at by Butts[4] that the Louisville of Kentucky is upper Lockport in age (see also under Guelph, page 73).

The Lockport dolomite, or "Niagara limestone" as it was formerly called, forms the upper and most important member of the Niagara formation. In Ontario, this dolomite gives rise to the most conspicuous of the Palæozoic cliffs, and outcrops in almost unbroken extent from Niagara falls (where the water pours over its very top) to Cockburn island at the head of lake Huron. The longest gap in the exposures is between Halfway rock at the north end of Bruce peninsula and Fitzwilliam island. The only exposures of Lockport for the intervening distance of 22 miles are a few minor ones on Bear Rump, Flowerpot, Lucas, and Yeo islands, the remainder of these islands and the other intervening islands being composed of Guelph dolomite.

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[1] For illustrations of the Lockport dolomite see Plates XXVIII A, XXIX A, XXX A, XXXII B, and XXXIII B.

[2] Kindle, E. M., Folio 190, p. 7

[3] New York State Mus., Mem. 5, p. 14

[4] [illegible] 99

The highest Lockport cliffs are those on Manitoulin island. Nea Fossil hill, about 4 miles southwest of Manitowaning, and also at Campbell bay, the Lockport arises as cliffs 200 feet in height.

The Lockport is nearly a true dolomite in composition with the exception of the DeCew, Gasport, and Eramosa divisions (see chemical analyses) When fresh, the rock is generally of a grey, or a pleasing blue-grey colour, but the familiar weathered surfaces are nearly white.

The total thickness of the Lockport dolomite at Niagara river is little less than 80 feet, or about 77 feet by Grabau's measurement. At Dundas, where the complete section is exposed, the thickness is about 135 feet. At Cabot head, the section is 160 feet thick and the top has not been recognized. On Manitoulin island, near Fossil hill, and also at Campbell bay as mentioned above, 200 feet of Lockport dolomite is expose in section without any Guelph beds having been found. The abov figures indicate the increasing thickness of the Lockport dolomite to th northwest, the lowest beds being probably older than the lowest Lockport beds in New York state. This is to be expected on the theory that th Lockport sea was an invasion from the north.

In the Niagara peninsula, the Lockport rests upon the Rochest shale. At Kelso the basal contact is with the Reynales dolomite a northward it is with the Cabot Head shales of the Cataract formation described already. In a formation of such thickness, it is natural expect that there will be considerable variation in bedding, character the rock, fossil content, etc. The Lockport has such variations, but f divisions have more than local significance. The subdivisions and mo detailed characters of the Lockport formation are described below. F the fauna, see table pages 64 68, and Plates XIV to XXI.

[1]*DeCew Waterlime Member.*

The basal member of the Lockport dolomite in the Niagara peninsu consists of a bed of argillaceous, dolomitic limestone, 8 to 9 feet thic which was formerly extensively worked at Thorold for the manufactu of "natural rock cement" (for analyses, see page 112). The "waterlim is fine grained and of a dark grey colour. As may be seen from Figur (page 22) this bed thins out at Stoney Creek and Hamilton to abou feet in thickness and has not been recognized to the west or north. Kelso, the 3-foot bed immediately overlying the Reynales dolomit typical Lockport dolomite in character and chemical properties (see p 173). At Limehouse, however, 6½ feet of thin-bedded, argillaceous, do mitic limestone was formerly worked for "natural rock cement." these beds *Dictyonema retiformis*, *Atrypa reticularis*, and *Dalman limulurus* occur. The first and last of these species are indicative Rochester affinities and suggest that the lower beds at Limehouse are equivalent of the DeCew beds. Other fossils in the DeCew are: at Thor

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[1] Sum. Rept., Geol. Surv., Can., 1913, p. 186

Strophonella patenta, *Schuchertella subplana*, and *Camarotoechia (Stegerhynchus) neglecta;* and at DeCew falls the Rochester species, *Caryocrinites ornatus*. Not only in fauna, but in composition also, the DeCew beds are closely related to the underlying Rochester shale. The waterlime is in fact a commingling of the dolomitic Lockport sediments with the argillaceous Rochester sediments. The characteristic nature of the DeCew beds may be seen in most of the exposures, and especially well in the Niagara gorge, along the New York Central and Hudson River railway north of Niagara university (see Plate XXX). Here and elsewhere the DeCew beds rest upon uneven eroded surfaces of Rochester shale, have churned structure, and present an eroded surface at the top into which the overlying dolomite fits. In general, the greater the irregularities at the top and bottom of the waterlime beds, the greater are the contortions within the beds themselves. Such characters point most clearly to a disturbance which was capable of affecting what are now the 8 or 9 feet of waterlime beds from top to bottom, before the solidification of the original shales, and either just before or at the time of marine calcareous sedimentation. The probable conditions existing at this time will be discussed below

Gasport Dolomite Member.

The term Gasport has been used by Kindle[1] for a 9-foot bed of pure, crinoidal, semicrystalline limestone occurring above the DeCew beds at Gasport and Lockport, New York. According to Kindle "Westward from Lockport the limestone becomes gradually more magnesian", and "The section on the Canadian side at Niagara Falls shows 7 feet of hard, grey, subcrystalline, crinoidal limestone, sharply differentiated from the saccharoidal dolomite above and the 9 feet of argillaceous limestone below, and clearly the equivalent of the Gasport limestone member at Lockport, although it is dolomitic throughout".

"On the American side of the gorge the bed is well exposed along the footpath to the river just south of the railroad bridges, where it has its usual crinoidal character but is 20 feet or more thick and is wholly dolomitic. Both there and farther south along the Niagara Gorge railway it contains large lenticular masses......... They are lighter in colour than the enclosing rock and on weathering crumble to fine, buff-coloured powder. They are of irregular outline and differ considerably in size, the larger ones having a diameter of 18 to 20 feet and a height of 8 to 10 feet. It is believed that they represent reefs of bryozoans".

As will be seen from the above description crinoidal, semicrystalline characters are the distinguishing features of the Gasport dolomite on the Ontario side of Niagara river. It is to be expected that a member which is differentiated only by the presence of crinoidal characters will vary much in thickness from place to place. Thus, westward from the Niagara river crinodal beds assigned to the Gasport are from 5 to 28 feet thick as follows: Ontario side Niagara river, 14 feet (Kindle gives 7 feet); DeCew falls, not recognized, but at St. Catharines Power Company nearby 23 feet; Grimsby, 12 to 14 feet; Stoney Creek, 7 feet; Hamilton, about 5 feet; Ancaster, 15 feet; Dundas, 13 feet; Waterdown, 8 feet. Farther north the term Gasport does not seem applicable as crinoid columns

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[1] U. S. Geol. Surv., Folio 190, p. 7

occur throughout the 70 feet of dolomite at Kelso, and elsewhere crinoida
zones occur at different horizons in the Lockport.

The Gasport is 20 to 28 feet thick at Thorold and is composed largel
of coral reefs which are full of fossils. The varied life of these reefs
suggested by the following numbers of genera and species which hav
been recognized. corals, 9 genera, 13 species; crinoids, 2 genera, 2 specie
brachiopods, 14 genera, 22 species; gastropods, 1 genus, 1 specie
cephalopods, 1 genus, 1 species; trilobites, 2 genera, 2 species.

Undivided Lockport Dolomite.

The great mass of Lockport dolomite has not been subdivided excep
into local facies and more or less local faunal zones. Leaving out th
DeCew and Gasport members, already described, and the Eramosa bed
described below, there is left the great central part of the Lockport dolomi
of Niagara peninsula, all but the upper beds from Kelso to Fitzwillia
island, and the whole formation on Manitoulin and Cockburn islands,
be described in a general way.

The Lockport, as already stated, is dominantly a light grey, or bl
semicrystalline, to fine-grained and compact, magnesian limestone appro
imating a true dolomite in chemical composition. Cavities and po
spaces are general. Chert nodules are plentiful at some local horizo
and argillaceous beds occur fairly commonly in the Niagara peninsu
The dolomites are generally in beds 2 to 3 feet thick, but thinner beds a
also much thicker beds are common. Jointing is general, is dominant
vertical, and very irregular. Where the rock is exposed at the surfa
erosion and solution by surface water has enlarged these joints to crac
that are in some cases a foot or more across.

Beds Containing Chert.

Chert nodules, 2 or more inches across, occur at different horizons
the Lockport formation. A zone of chert nodules is reported by Clarke a
Ruedemann[1] as occurring at the top of the thin Eramosa beds (determin
by the writer) at Niagara falls. It is this chert horizon which is suppo
to represent the location of the upper Shelby fauna (Guelph). Ch
beds 5 feet thick occur 10 feet lower in the section exposed near the Onta
end of the international bridge.

The chert horizon has probably been eroded away in the section along
Niagara escarpment between Niagara falls and Stoney Creek. So
chert occurs at Stoney Creek in the beds immediately above the Gasp
dolomite. At Mount Albion and Hamilton numerous chert nodules oc
in the 60 feet of dolomite overlying the Gasport. From these nodu
Colonel C. C. Grant collected many sponges. At Ancaster the chert b
are 16 feet or more thick and at Dundas they are 40 feet thick; at b
places they rest upon the Gasport dolomite.

No chert beds were noted in the sections between Dundas and Ca
head. In the bluffs at Cabot head, a limited zone of chert nodules oc
about 15 feet above the base of the Lockport formation and immediat
above beds full of *Pentamerus oblongus.* Scattered chert nodules

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[1] New York State Mus., Mem. 5, p. 14

occur high up in the coral horizon at Cabot head and also on Manitoulin island. At Campbell bay, on Bayfield sound, 12 feet of fossiliferous chert beds occur about 180 feet abode the base of the Lockport dolomite. A very remarkable chert horizon belonging near the top of the Lockport dolomite is exposed north of Old Quarry point, near the western end of Manitoulin island. Here, angular pieces of white chert 4 to 6 inches across, derived from the underlying beds, are scattered about on the surface of the rock. This chert zone is probably 15 feet thick.

Beds Containing Pentamerus Oblongus.

Pentamerus Oblongus, which is fairly common in the Clinton, Reynales beds of Niagara peninsula, appears to be nearly or quite absent for many miles to the north. At Owen Sound, however, the lower 5 feet of Lockport beds are crowded full of *Pentamerus oblongus*, the typical Lockport corals occurring just above. About 15 feet of basal dolomite at Wiarton is similarly crowded with this interesting brachiopod. Similar beds 4 or 5 feet thick occur at Lionhead and Dyer bay, and 2 feet of these beds occur at Cabot head. At Lionhead and Cabot head, however, 8 to 10 feet of thin, even-bedded dolomite occurs beneath the Pentamerus beds. The contact is sharp, the thin beds containing few fossils, and the Pentamerus beds being very fossiliferous. At Cabot head, the thin beds contain *Favosites favosus*, *Camarotachia neglecta*, and a *Cœlocaulus* resembling *longispira*. It seems fairly certain, therefore, that the thin beds are basal Lockport. At Dyer bay, the basal beds are mostly obscured, and to the northward they are generally obscured as far west as West bay on Manitoulin island. Here, above 6 feet of soft, green Cataract shale, 20 feet of fine-grained, grey dolomite occurs with shale partings near the base. No fossils were found in these beds but they are probably basal Lockport.

Fossil Hill Coral Horizon.

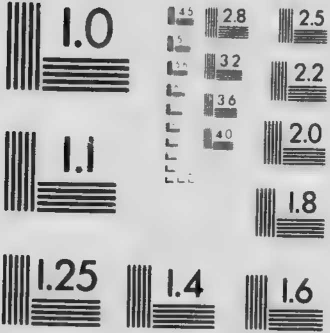
The more northern occurrences of the Lockport dolomite are remarkable for the variety and numbers of their corals. These fossils are limited mostly to definite zones, which record suitable environment, as might be expected from a knowledge of the restricted conditions of temperature and pressure under which corals live. The corals at Fossil hill, about 7 miles southwest of Manitowaning, occur in great profusion about 70 feet up in the Lockport dolomite and appear to represent the acme of coral environment. It might not be expected that such favourable conditions prevailed widely at the geological moment recorded at Fossil hill, and yet similar coral assemblages are met with at approximately the same horizon at Cabot head, Campbell bay, Cockburn island, and elsewhere.

The "Barton Beds".

The 80 to 90 feet of Lockport, overlying the chert beds and underlying the Guelph dolomite in the vicinity of Hamilton, are decidedly argillaceous and contain shale beds at some horizons. Spencer and Grant named these beds the "Barton beds," after the name of the township in which Hamilton is situated. The name "Barton" has never been

MICROCOPY RESOLUTION TEST CHART

ANSI and ISO TEST CHART No 2



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recognized to any extent in geological literature as it was pre-occupied in the Tertiary of England; it has, however, considerable local significance. As will be seen later, the upper 35 feet of the "Barton beds" belong to the Eramosa dolomite. The lower part is well-defined by its argillaceous character from Mount Albion to Ancaster.

Lockport Dolomite not Differentiated.

Northward from the Niagara peninsula, the greater part of the Lockport dolomite is undifferentiated. It differs considerably in bedding and characters, but is generally thick-bedded to massive, typical dolomite, blue, grey, or less commonly buff on fresh fracture, and weathering white.

[1]*Eramosa Member.*

The Eramosa beds consist characteristically of thin, even-bedded, argillaceous, arenaceous or bituminous dolomites. They are sparingly fossiliferous. These beds occur at the top of the Lockport formation throughout the western peninsula of Ontario and on the islands to the north as far as Fitzwilliam island. Good sections of the Eramosa beds, however, are few, the following being the best known (Figure 3): Niagara Falls, New York, 12 feet of thin, even-bedded dolomites with bituminous partings, their top being at the crest of the American falls; Ancaster, not well-differentiated but about 35 feet of brown-grey dolomite, with bedding planes marked by change of colour; Dundas, about 35 feet of dark blue, argillaceous dolomite, shaly at base and with bituminous partings at top; Guelph, 30 feet or more of a chocolate brown, bituminous shale and dolomite; Wiarton, about 50 feet of dark grey, thin-bedded dolomite, very cleavable and even-bedded in the upper 15 feet, which are quarried for flags and dimension stone; Halfway rock, 30 feet of thin-bedded dolomite. The upper part of the Eramosa beds are seen in the lower part of the "flowerpots" of Flowerpot island (see Plate I). On the western end of Fitzwilliam island, typical Eramosa beds occur at the top of the Lockport; their thickness is probably about 30 feet. On Manitoulin island the Eramosa beds have not been recognized and appear to have been eroded away.

The Eramosa beds are marked by dome structure, the dimensions of the domes varying from a few feet to 100 or 200 feet across, with a centre elevation of 15 to 20 feet. Good examples of the larger domes occur at Guelph, where one exposure south of the prison farm has the top of the dome stripped away, revealing a dome-shaped coral reef which in this case at least was the cause of the structure in the Eramosa beds.[2] This reef contains a fauna which is transitional from the Lockport into the Guelph.

Few fossils have been found in the Eramosa beds, excepting at Guelph[3]. The revised list of those collected by the writer from an horizon about 25 feet below the top of the Eramosa beds is as follows: *Monomorella* cf *orbicularis* Billings, *Orbiculoidea subplana* (Hall), *Orthis?* near *tenuidens*

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[1] Geol. Surv., Can., Mus. Bull. 20, p. 1
[2] Ibid, p. 2
[3] Ibid, p. 3

Hall, *Camarotœchia (Stegerhynchus) whitei* (Hall)? *Spirifer radiatus* Sowerby? *Whitfieldella nitida* Hall?, *Orthoceras*, *Eusarcus logani* Williams.

The approximate chemical composition of the fossil horizon at Guelph as determined by E. Poitevin of this Survey, is as follows: insoluble matter including iron oxide, 50 per cent; bituminous matter, 25 per cent; calcium carbonate with a trace of magnesia, 25 per cent.

As already stated, the lower fossil horizon, containing *Monomorella* cf *orbicularis*, is suggestive of the lower Shelby horizon of New York state, and the true Guelph above is probably represented in New York by the upper Shelby horizon which, therefore, would mark the base of the Guelph formation.

Distribution of Lockport Fauna.

Genera and species.	Western New York.	Niagara river.	Thorold.	DeCew. DeCew falls.	Gasport. DeCew falls.	Gasport boulders. Grimsby.	Higher beds. Grimsby.	Stoney Creek.	Gasport. Hamilton.	Chert. Hamilton.	Higher. Hamilton.	Dundas.	Lower 15 feet. Limehouse.	Upper. Rockwood.	Reef near top and Eramosa. Guelph.	30-100 feet up. Kolapore.	Lower. Owen Sound.	30 feet up. Owen Sound.	Lower 8 feet. Wiarton.	125 feet up. Wiarton.	Upper. Purple valley.	Lower. Barrow bay.	Upper. Stokes bay.	Basal. Cabot head.	30 feet up. Cabot head.	High up. Cabot head.	Near base. Fitzwilliam island.	Higher. Fitzwilliam island.	170 feet up. Fitzwilliam island.	Hungerford point.	Middle. Tamarack cove.	Upper. South bay.	80 ft. up to 100 ft. up. Fossil hill.	Middle. Sandfield.	Upper. Michael bay.	Upper. Providence bay.	80 ft. up. Kagawong lake.	Upper. Quarry point.	100? ft. up. Cockburn island.
Plants.																																							
Buthotrephis gracilis (Hall)								q																															
Buthotrephis gracilis crassa Hall										q																													
Porifera.																																							
Astylospongia præmorsa (Goldfuss).										?																													
Hydrozoa.																																							
Dictyonema retiforme (Hall)													q																										
Dictyonema gracile Hall								q	q																														
Actinostroma whiteavesi niagarense Parks			P																																				
Clathrodictyon vesiculosum Nicholson and Murie							P				P																						P						
Clathrodictyon variolare (Von Rosen).																																	P						
Clathrodictyon striatellum (D'Orbigny)											P							P																					
Clathrodictyon ostiolatum (Nicholson)											P							P?															P						
Lophiostroma magnum Parks																																	P						
Rosenella? manitoulinensis Parks.																																	P						
Stromatopora constellata Hall											P																						P						
Stromatopora antiqua (Nicholson and Murie)			P																																				
Ceramoporella? irregularis (Whitfield)											P																												
Anthozoa.																																							
Enterolasma caliculum (Hall)			q											q																									
Streptelasma spongaxis (Rominger)																															q								

Zaphrentis stokesi Edwards and Haime																q																							
Amplexus shumardi (Edwards and Haime)																																	q			q			q
Pycnostylus guelphensis Whiteaves															q																		q						
Pycnostylus elegans Whiteaves															q																								
Ptychophyllum stokesi Edwards and Haime															q																								
Cystiphyllum niagarense (Hall)	B		q		q						?														q	q		q				q	q		q	q	q		
Chonophyllum canadense (Billings)																									q							q	q						
Strombodes diffluens Edwards and Haime																																			q				
Strombodes eximius Billings																	L								q														
Strombodes pentagonus Goldfuss																										q				q			L						
Cyathophyllum thoroldense Lambe			L																						q				q				q						
[1]Synaptophyllum multicaule (Hall)			q														q																						
Diplophyllum cæspitosum Hall			q														..																q						
Cystiphorolites major (Rominger)																							q																
Syringopora bifurcata Lonsdale																																	q						
Syringopora retiformis Billings																																	q						
Syringopora verticillata Goldfuss																	B							q		q	q				q		q			?			
Syringopora fibrata Rominger																															q		q			q			
Cannapora junciformis Hall																																	q						
Vermipora niagarensis Rominger																																			q	q			
Favosites constrictus (Hall)			q			q					q																						?						
Favosites favosus (Goldfuss)			q																																				
Favosites hisingeri Edwards and Haime			q																	q				q			q	q			q	q	q		q	q	q	q	q
Favosites hispidus Rominger															q																q	q	q		q		q		
Favosites niagarensis (Hall)	B	G	q											q	q			q															q					q	?
Paleofavosites asper D'Orbigny			q																						q								q						
Syringolites huronensis (Hinde)																									q														
Thecia major Rominger																																	L						
Alveolites thoroldensis Parks			P																														q						
Alveolites labechei Edwards and Haime																																							
Cladopora fibrosa Hall	B																	L															L						
Cladopora laqueata Rominger																																							
Cladopora reticulata Hall																																	q						
Cœnites crassus (Rominger)																																		q					
Cœnites juniperinus Eichwald			L																														q						
Cœnites laminatus (Hall)	B																																						
Cœnites ramulosus (Hall)	B																									q	q						q	q					
Striatopora flexuosa Hall														q																									
Halysites catenularia (Linnaeus)	B	G	q				q																				q						q						
Halysites catenularia microporus (Whitfield)																							q		q	q			q		q	q	q				q	q	q
Lyellia americana Edwards and Haime																									q	q		q		q	q	q	q			q	q	q	q
Lyellia affinis (Billings)			L																							q							q						
Lyellia superba (Billings)																																							
Lyellia decipiens Rominger																										L							q						
Heliolites elegans Hall	B		q																						q							q	q						
Heliolites interstinctus (Linnaeus)																									q						q								
Heliolites megastoma (McCoy)																									q								q	q	q				

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[1] Classification revised by Chadwick.

Distribution of Lockport Fauna—Continued.

Genera and species	Western New York.	Niagara river.	Thorold	DeCew. DeCew falls.	Gasport.	Gasport boulders. Grimsby.	Higher beds.	Stoney Creek.	Gasport.	Chert. Hamilton.	Higher.	Dundas.	Lower 15 feet. Limehouse.	Upper. Rockwood.	Reef near top and Eramosa. Guelph.	50-100 feet up. Kolapore.	Lower. Owen Sound.	50 feet up.	Lower 8 feet. Wiarton.	125 feet up.	Upper. Purple valley.	Lower. Barrow bay.	Upper. Stokes bay.	Basal.	30 feet up. Cabot head.	High up.	Near base.	Higher. Fitzwilliam island.	170 feet up.	Hungerford point.	Middle. Tamarac e.	Upper. South ba	80 ft. up to 100 ft. u. Fossil hill.	Middle. Sandfield	Upper. Michael bay	Upper. Providence bay.	80 ft. up. Kagawong lake.	Upper. Quarry point	100 ft. up. Cockburn island.
Anthozoa—Con.																																							
Heliolites pyriformis Guettard	B																																q	q			q		
Heliolites spiniporus Hall	B														q																								
Heliolites subtubulatus (McCoy)																																					q		
Plasmopora follis Edwards and Haime			q																														q			q	q		
Protaræa walkeri (Spencer).											p																												
Cystoidea.																																							
Caryocrinites ornatus Say				q		q																																	
Crinoidea.																																							
Periechocrinus speciosus (Hall)	B		q																																				
Ichthyocrinus laevis Conrad			q																																				
Eucalyptocrinus caelatus laevis Grabau and Shimer		c																																					
Dendrocrinus caduceus (Hall)																										cf													
Bryozoa.																																							
Lichenalia concentrica Hall			q			q		q																															
Brachiopoda.																																							
Orbiculoidea subplana (Hall).															q																								
Schizotreta tenuilamellata (Hall)	B							q						q																									
Dictyonella corallifera (Hall)						q																																	
Stropheodonta profunda (Hall).			q																																				
Strophonella striata (Hall)								q																															

Brachiop a.																												
Orbiculoidea subplana (Hall).													a															
Schizotreta tenuilamellata (Hall)	B						a					a																
Dictyonella corallifera (Hall)					a																							
Stropheodonta profunda (Hall).			a																									
Strophonella striata (Hall)					?		a																					
Strophonella patenta (Hall			a	a			a																					
Leptaena rhomboidalis Wilckens	B	a	a		a						a								a									
Schuchertella subplana (Conrad			a				a																					
[1]Schizophoria punctostriata Hall			a																									
Schizophoria flabellites Foerste.																												
Platystrophia biforata (Schlotheim)			a				a																	a			a	
Bilobites acutilobus (Ringueberg)			a																					a				
Dalmanella elegantula (Dalman)			a								a																	
Rhipidomella hybrida (Sowerby)	B		a																									
Conchidium occidentale Hall																												
Stricklandinia manitouensis Williams n. sp																					a							a
Pentamerus oblongus Sowerby																									a			
Clorinda ventricosa (Hall)		a	a		a										a		a	a		a		a	a	a	a	a		
Rhynchotreta cuneata americana (Hall)	B	a	a	a	a						a	a	a															
Camarotœchia neglecta (Hall)			a		a								a															
Camarotœchia whitei (Hall)													a											a				
Camarotœchia ? acinus (Hall)					a																							
Camarotœchia ? indianensis (Hall)					a																							
Atrypa reticularis (Linnaeus)	B	a	a				a		a		a	a							a					a				
Atrypa nodostriata Hall			a		a						a										a							
Cyrtia meta (Hall)					a																							
Spirifer niagarensis (Conrad)			a		a																							
Spirifer radiatus (Sowerby)			a		a	a				a		a	a						a				a					
Spirifer crispus (Hisinger)			a	a		a	a		a												a							
Spirifer eudora (Hall)		a	a		a							a							a									
Homœospira apriniformis Hall		a																										
Whitfieldella nitida (Hall)			a																					a	a			
Whitfieldella nitida oblata (Hall)			a		a								a															
Whitfieldella intermedia (Hall)			a																									
Whitfieldella cylindrica (Hall)			a						a																			
Pelecypoda.																												
Matheria recta (Hall)																												
Amphicœlia leidyi Hall																					a							
Mytilarea acutirostra (Hall)																			a		a							
Streptomytilus aphaea (Hall														a							a							
Goniophora speciosa Hall					a														a									
Gastropoda.																												
Eotomaria kayseri Clarke and Ruedemann.																												
Cœlocaulus longispira (Hall)																			a									
Cœlocaulus bivittatus (Hall)																						a						
Holopea guelphensis Billings												a																
Diaphorostoma hemisphericum Hall.				a															a									
Diaphorostoma niagarense (Hall)	B		a					a	a	a	a	a		a											a			
Conularida.																												
Conularia niagarensis Hall								a																				
Cephalopoda.																												
Orthoceras imbricatum (Wahlenberg). .																a												
Orthoceras brucensis Williams n. sp											a																	

[1] Classification revised by Chadwick

Destribution of Lockport Fauna—Concluded.

Genera and species.	Western New York.	Niagara river.	Thorold	DeCew. DeCew falls.	Gasport. DeCew falls.	?Gasport boulders. Grimsby.	Higher beds. Grimsby.	Stoney Creek.	Gasport. Hamilton.	Chert. Hamilton.	Higher. Hamilton.	Dundas.	Lower 15 feet. Limehouse.	Upper. Rockwood.	Reef near top and Eramosa. Guelph.	50 100 feet up. Kolapore.	Lower. Owen Sound.	50 feet up. Owen Sound.	Lower 8 feet. Wiarton.	125 feet up. Wiarton.	Upper. Purple valley.	Lower. Burrow bay.	Upper. Stokes bay.	Basal. Cabot head.	30 feet up. Cabot head.	High up. Cabot head.	Near base. Fitzwilliam island.	Higher. Fitzwilliam island.	170 feet up. Fitzwilliam island.	Hungerford point.	Middle. Tamarack cove.	Upper. South bay.	80 ft. up to 100 ft. up. Fossil hill.	Middle. Sandfield.	Upper. Michael bay.	Upper. Providence bay.	80 ft. up. Kagawong lake	Upper. (? point.	100? ft. up kburn island.
Cephalopoda—Con.																																							
Dawsonoceras annulatum (Sowerby)	B	G	q					q					q													q													
Kionoceras cancellatum (Hall)	?												q																										
Protokionoceras trusitum (Clarke and Ruedemann)																					q																		
Trochoceras costatum (Hall)																					q																		
Discosorus gracilis Foord																																		q					
Huronia vertebralis Stokes																																q							
Trilobita.																																							
Bumastis ioxus (Hall)			q			?			q				q																										
Goldius niagarensis (Hall)		G				q																																	
Calymene niagarensis Hall	B		q			?																																	
Sphærexochus romingeri Hall						q																																	
Dalmanites limulurus (Green)						q		q	q																														
Eurypterida.																																							
Eusarcus logani Williams															q																								

NOTE.—P, reported by Parks. G, reported by Grabau. q, found by author. L, reported by Lambe. B, reported in Bassler's Index.
[1]Classification revised by Chadwick.

The Rochester shale is an extension westward of the Rochester shale of New York state and is generally correlated with the Osgood limestone and shale of west Tennessee, Ohio, and Kentucky and, according to Bassler, with the West Union limestone of southern Ohio and eastern Kentucky and the upper St. Clair limestone of northern Arkansas. Twenhofel[1] correlated his Chicotte formation of Anticosti island "on stratigraphic grounds..........with the Irondequoit-Rochester of the New York section." The Rochester has been correlated by Schuchert and Twenhofel with the McAdam formation of Arisaig, which McLearn[2] correlates with "the Salopian" of Great Britain "without regard........to its component divisions".

The Lockport formation of Ontario and New York state is to be correlated with the Laurel dolomites, the Waldron shale, and the Louisville magnesian limestone of Kentucky[3], the Glenkirk limestone of west Tennessee, the Hopkinton dolomite of Iowa and Minnesota, and a part of the Bainbridge limestone of east Missouri and Illinois[4]. Savage[5] has recently claimed that the Mayville limestone of Wisconsin is the equivalent of some part of the Alexandrian series of Illinois and Missouri and the author correlates the Racine of Wisconsin with the lower Guelph of Ontario; thus only the Waukesha beds, including the Byron, lower and upper coral beds, remain to be correlated with the Lockport dolomite of New York and Ontario. These subdivisions may yet be traced into Ontario, the chert horizon containing fossils at Campbell bay, Manitoulin island, suggesting strongly the upper Coral beds[6].

The long recognized Niagara strata of lake Timiskaming region have been shown by the author to contain a coral horizon closely resembling that at Fossil hill, thus indicating its relationship to the Lockport. Schuchert[7] has correlated with the Louisville, deposits occurring along the west shore of James and Hudson bays, in the lake region of Manitoba in southeastern Alaska, and on nearly all the islands of the Arctic archipelago north of Canada. Although much remains to be learned of these little studied regions, the fossils in many cases suggest Lockport affinities. For example, coral reefs containing "*Favosites gothlandicus* Lamarck, *Heliolites interstincta* (Linn.), and *Halysites catenulatus* (Linn.) var.,"[8] found on the 141st meridian between Yukon and Alaska by the author, while assistant to D. D. Cairnes, suggest the Lockport coral horizon. The fossils collected by A. P. Low[9] in 1904, on Southampton island, Hudson strait, include "*Favosites gothlandicus, Syringopora verticillata, Halysites catenularia*, and *Plasmopora follis*," all of which are typical Lockport corals.

The Lockport is to be correlated with the Moydart[10] formation of Arisaig and the upper Wenlock of Norway.

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[1] Ibid, p. 21.
[2] Am. Jour. Sc., vol. XLV, 1918, p. 135.
[3] Kentucky Geol. Surv., ser. IV, vol. III, pt. II, 1914-15, pp. 84, 86, 99.
[4] U.S. Nat. Mus. Bull. No. 92, vol. II, 1915, pls. 3 and 4.
[5] Bull. Geol. Soc. Am., vol. XXVII, No. 2, 1916, p. 308
[6] Geol. of Wis., vol. II, p. 351.
[7] Bull. Geol. Soc. Am., vol. XX, 1908, pl. 67
[8] Cairnes, D. D., Geol. Surv., Can., Mem. 67, p. 74
[9] Cruise of the Neptune, 1906, Appendix IV, pp. 325-6
[10] Geol. Surv., Can. Mem. 60, 1914, p. 60

NOTE.—P, reported by Parks. G, reported by Grabau. q, found by author. L, reported by Lambe. B, reported in Bassler's Index.
¹Classification revised by Chadwick.

NIAGARA SEDIMENTATION.

From the foregoing evidence, it is clear that Niagara time commenced with seas which in places received large quantities of mud washed in from the surrounding land, the deposits forming the Rochester shale. Either the younger formations to the north were elevated above the land and were actively eroded during Rochester sedimentation or else (as believed by Chadwick) an emergence followed Rochester deposition during which not only Rochester sediments but younger sediments to the north were eroded away. With the succeeding submergence came an overlapping of the dolomitic deposits of the Lockport sea from the north extending over higher and higher Rochester deposits (according to Chadwick) well into New York state. On the basis of this overlap, the DeCew beds must be regarded as reworked Rochester shale, their final condition being probably due to the action of currents and waves of the encroaching sea, upon loose materials derived from land erosion. The fossils contained in the DeCew beds would thus be, either dead forms contained in the Rochester shale or forms introduced under the new conditions of Lockport sedimentation As a matter of fact their affinities are mostly with the Rochester and they do not indicate any apparent wear.

Kindle[1] has shown that beds similar to the DeCew waterlime are being formed to-day in the bay of Fundy as the result of deposition and scour and although the widespread DeCew beds may not be compared directly with the modern formations of the bay of Fundy, the origin of the latter beds is instructive. The higher dolomites were deposited in widespreading seas, which were of such depth and temperature as to promote the growth of coral reefs even within the Arctic regions. A partial emergence of the land caused an inflow of sufficient detrital material to give the Eramosa beds their argillaceous and arenaceous character, these beds being deposited against and over coral reefs whose development they arrested. This period of diminishing seas closed Niagara time, the succeeding deposits being Guelph.

GUELPH FORMATION.[2]

DESCRIPTION, EXTENT, AND SECTIONS.

The Guelph is a great dolomite formation of fairly uniform character which overlies the Lockport dolomite and is overlain by the Salina formation. The weathered rock is light grey or cream-coloured and generally has a porous, saccharoidal texture. Some beds, however, are compact fine-grained, and very hard. The beds vary from a few inches to several feet in thickness, the thicker beds being most common.

The Guelph formation underlies a belt of country in Ontario extending from Niagara river to the head of Bruce peninsula and occurs on the islands to the north as far as Fitzwilliam island. In Niagara peninsula this belt averages about 5 miles across, and from Hamilton to Chiefs point the average is about 13 miles. On Bruce peninsula the Guelph is divided into areas, isolated by denudation. Unlike the underlying Lockport, the Guelph dolomite does not occur as prominent cliffs except at the northern end of

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[1] Bull. Geol. Soc. Am., vol. 28, 1917, pp. 323-334.

[2] For illustrations of the Guelph dolomite, see Plates I, XXVIIA, XXXIIA, XXXIII, XXXIVB.

Bruce peninsula and in the islands immediately to the north. Elsewhere the rock is exposed as shelving ledges along the shore of the west side of Bruce peninsula, as glaciated exposures protruding through the surface deposits over large areas of Bruce peninsula and to a less extent in Grey and Wentworth counties, and in the valleys of streams, notably the Rocky Saugeen and Grand rivers and the upper waters of Twentymile creek (see Maps 1714 and 1715 for exposures).

Owing to the lack of complete sections, the thickness of the Guelph formation is difficult to measure. Logan estimated it on the basis of dip to be about 160 feet thick in the vicinity of Breslau.[1] He moreover, described the section at Elora as 82 feet thick and the section at Fergus as 20 feet thick "which would underlie the preceding." He placed the strata farther up the Grand river as still lower.

The writer followed the section from Fergus to Elora along the Grand river at low water and found that the river descends at a higher angle than the dip of the formation and in consequence the top beds at Fergus are about 10 feet higher than the top of the section at Elora and about the same as the top beds at Salem 1 mile northwest of Elora. The exposures above Fergus appear similar to those at Fergus and give little additional information.

The Salem-Elora section represents all the strata recognized and was found to measure about 82 feet as stated by Logan. The section consists for the most part of compact, fine-grained dolomite and is as follows in ascending order: 13 feet of thin-bedded dolomite containing *Favosites favosus*, *Pycnostylus guelphensis*, and *stromatoporoids;* 19 feet of beds 2 to 3 feet thick containing *Megalomus canadensis* in the lower 12 feet; 8 feet of beds 3 to 4 feet thick containing *M. canadensis;* 20 feet of hard, fine-grained, light buff beds about 2 feet thick; 12 feet of thinner beds at the top of the section containing *Conchidium occidentale*, *Caloceulus* sp., and *M. canadensis.* In places the thicker beds appear quite massive and no division extends very far laterally. Ten feet of higher strata occur at the top of the section at the steel bridge over a branch stream near Salem and consist of fine-grained, compact, rather thick beds containing *M. canadensis* about 8 feet below the top.

The best method now available for measuring the thickness of the Guelph is by reference to well records. Measurements cannot be derived directly, however, as it is difficult to recognize in well records the division between the Lockport and Guelph formations. The Lockport has, however, been measured in section both at Niagara river (77 feet) and Dundas [illegible] feet) (see page 58) and in a well sunk at Guelph[2] the "blue slate" (Eramosa beds) is 50 feet and the dolomite below is 100 feet thick. The Lockport [illegible] is 150 feet thick. Assuming these measurements to hold approximately within a few miles radius of the locality where they were made, we arrive at the following thicknesses for the Guelph: on lot 2, concession IV, Willoughby township, Welland county,[3] the combined thickness of the Guelph and Niagara dolomite is 220 feet; taking the Lockport as 80 [illegible] the Guelph is 140 feet thick. As this well [illegible] only 6 miles from Niag[illegible] the measurement may be considered very nearly correct. A [illegible] at Kitchener[4] gives what may be interpreted as the thickness of the Guelph and Niagara dolomite as 240 feet. Taking the thickness of the Lockport as 150 feet as at Guelph, the Guelph formation would be 90 feet thick. Considerable difference of thickness is thus indicated and it is probable that this is to be explained by an erosion surface at the top of the Guelph, which is clearly suggested by the varying thicknesses of the combined Guelph and Lockport dolomites seen in the cross-section from Dunnville to Grimsby (see Map 1714) and in the well records of Kent county (see Figure 4). It will be noted that 90 feet compares rather closely with the section as measured at Elora. The Elora section is certainly not complete, but may not lack as much as Logan supposed. Northward, little reliable information is at hand as to the thickness of the Guelph formation.

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[1] Geolog [illegible]

[2] Rept. Ont. Bur. [illegible] Mines 1903, p. 150

[3] Well record, Jour. [illegible] Min. Inst., vol. III, p. 77

[4] Geol. Surv. [illegible] pt. II, p. 42A

The base of the Guelph dolomite is clearly exposed in the eastern part of the city of Guelph, where it rests on the Eramosa beds. The lowest bed is about 2 feet thick and is bituminous, with a smell resembling that of petroleum. Thinner, light brown, nodular beds succeed, about 12 feet being exposed along the Canadian Pacific railway near Eramosa river. *Pycnostylus guelphensis* occurs about 8 feet above the base. The base of the Guelph is also exposed at Niagara river, at Dundas, in the vicinity of Wiarton, at Stokes bay, at Halfway rock (about midway between Cabot head and Tobermory), and on Bear Rump, Flowerpot, Echo, and Fitzwilliam islands.

Between the city of Guelph and Niagara river the weathered basal Guelph beds, averaging about 2 to 4 feet in thickness, are brown, have bituminous partings, and a smell resembling that of petroleum. They are also commonly full of cavities which contain at Niagara gorge[1] "pearl spar or dolomite". In the vicinity of Wiarton and northward the basal Guelph is massive, full of cavities and pore spaces but does not have bituminous partings or an oily smell.

The Standard White Lime quarry in the southwestern part of the city of Guelph is in strata that are probably from 40 to 60 feet above the base of the Guelph formation. The section includes about 20 feet of creamy white, porous, saccharoidal dolomite, the beds being 3 to 4 feet thick near the base and thin (probably due to weathering) near the top. *Stromatoporoids* and *Cœlocaulus* (more than one species) are common near the base, *Pycnostylus guelphensis* occurs about 8 feet up, and *Trimerellas* and *Megalomus canadensis* occur near the top.

As already stated, beds high up in the Guelph formation are represented at the top of the Salem-Elora section. The sections at Galt and between Galt and Glen Morris (on the Grand river about 6 miles below Galt) include the highest Guelph beds known to outcrop in Ontario. The highest beds of all are exposed at or near water-level in the river above Glen Morris. The dolomite is badly water-stained, occurs in beds about 10 inches in thickness, and is fine-grained and very hard. On fresh fracture it is buff grey. *Megalomus canadensis* was found in most of the exposures. Because of the isolated outcrops and the variations in the dip of the bedding the thickness of exposed strata could not be determined. Logan[2] has described the Galt section as consisting of "twenty feet of yellowish-white and greyish-white, crystalline, thick-bedded dolomite" at the base, succeeded upward by "thirteen feet of pale buff or white dolomite", and "eighteen et of hard, thin-bedded, bluish dolomite" at the top. He continues, "the whole mass holds fossils, but these, in [illegible] immediate vicinity of Galt, are most abundant in the twenty feet of p[illegible]uff, thin-bedded dolomite in the middle of the section". The strata downstream are evidently included by Logan in the upper beds and probably do not represent more than the 20 feet allowed by him, as the river runs nearly on the strike of the formation. 34 feet of section is exposed at Galt above the river bed.

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[1] Bull. N.Y. State Mus., No. 45, 1901, p. 112
[2] Geol. Surv., Can., 1863, p. 339

At Niagara falls, all the rock above the bank of the falls is Guelph. According to the section given by Clarke and Ru[illegible] of Guelph dolomite is represented in the vicinity of the falls, the [illegible] being at the car barn on the gorge route (basal), on Goat island, and on Three Sisters islands. This section is as follows in ascending order: "8 feet of brown, thin-bedded dolomites with rough surface and black partings", 10 feet not exposed, "25 feet brown dolomites exposed at Goat island and Three Sisters islands with summit near head of rapids. Full of cavities with *Stromatopora, Halysites.* Weathers very scraggy. Uppermost bed (4 feet) sandy."

Besides the Fergus-Elora section, a fair section is exposed on the Rocky Saugeen river at Hayward falls just below Rocky Saugeen post-office. The gorge in the rock is 30 to 40 feet deep and in all 90 feet of rock is exposed. The surfaces are badly weathered and caves occur near the tail-race of a mill. The rock is thick-bedded to massive and contains numerous fossils, most of which were found above the middle of the section. [illegible]*osites hisingeri?, Pycnostylus guelphensis, Megalomus canadensis, Con*[illegible]*dium occidentele*, and *Stromatoporoids* were recognized.

Good outcrops also occur at Durham, from which many fine specimens were obtained by Mr. J. Townsend and other early collectors.

In the vicinity of Wiarton, as already mentioned, the base of the Guelph is well exposed. The best exposures are about two miles northwest from Wiarton on the road to Oliphant where the Eramosa beds are quarried. The actual contact with the base of the Guelph is obscure, 5 or 6 feet of strata being talus-covered. About 15 feet of Guelph strata, however, are exposed in a cliff to the north and consist of porous, scraggy, rather thick-bedded dolomite containing *Pycnostylus guelphensis, Spirifer eudora*, and *Stropheodonta* sp. At a zinc prospect about 4 miles northwest of Wiarton on the north half of lot 30, concession II, Albemarle East township, Bruce peninsula, an open-cut has been made in prospecting for zinc blende. The cut starts in rock that is about 40 feet above the base of the Guelph and is 30 feet deep, thus supplementing the section just mentioned. The rock, which is light grey in colour, is very porous and scraggy and full of cavities, many of which contain zinc blende. In the dump from this excavation, many fossils have been obtained; these are quite unlike Guelph assemblages found elsewhere in Ontario and very similar to the fauna of the Racine beds of Wisconsin. The outstanding features of the fauna are the large number and variety of cephalopods present. Most of these cannot be definitely determined because of their poor preservation, those recognized being given in the following table (pages 77-79). An unidentified *Phragmoceras* is also very common. The most typical Guelph species present is *Pycnostylus guelphensis.*

Higher Guelph strata occur along the western side of Bruce peninsula, and many specimens of *Megalomus canadensis* occur in the strata along

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[1] Clarke and Ruedemann, p. 14

the shore between Stokes bay and cape Hurd. Beds at Stokes bay within the lowest 50 feet of the Guelph formation are crowded with very large crinoid columnals. Some of these are three-quarters of an inch in diameter. It was formerly thought that the Guelph formation in Ontario was almost free from crinoid remains, and this is mostly true for the southern and better known outcrops. In the north, however, crinoid stems are common and some of the lower beds are almost entirely made up of them.

The Fishing islands west of Oliphant and the islands north of Tobermory, have excellent Guelph exposures. The lower beds, as for example at Halfway rock, Bear Rump, Flowerpot, Middle, Lucas, Yeo, and Fitzwilliam islands, have been recognized primarily by their stratigraphic position above the Eramosa beds. These upper Lockport beds extend to the northeast, at the localities mentioned, from beneath the Guelph capping rock, with the exception that on Bear Rump island the Eramosa beds project to the southwest from beneath the higher strata. Guelph fossils were found at each of the above-named localities, however, and thus the age of the rock was verified. For higher beds, age determination depends upon location and fossil evidence. Casts of species of *Trimerella* and *Rhinobolus* are of great value in determining the age of the northern Guelph outcrops.

Reef structures occur on Middle or "Plucky island" and on Lucas and Yeo islands. In fact it is to massive reef structure that these small islands owe their preservation.

"Plucky", or middle island as it is known on the chart, is a mere islet situated about halfway between Tobermory and Flowerpot island and is not shown on the geological map. It appears as a mass of tumbled blocks of dolomite, 30 or 40 feet high, but on closer inspection it proves to have a core of solid rock from which the blocks have fallen, being undermined by wave action. The solid rock is a *stromatoporoid-coral* reef. The reef building corals were *Pycnostylus guelphensis* and *Pycnostylus elegans*. Along with the reef builders, *Favosites favosus, Rhinobolus guelphensis*, and *Trimerella grandis?* occur. The top of Lucas island appears to be the remains of a *stromatoporoid* reef resting on Eramosa beds. The maximun elevation is about 30 feet. Yeo island is low, probably not more than 20 feet high at any place, and is a domed-reef structure resting on more or less domed Eramosa beds which are incised by wave action on the northeast angle. The reef builders were *Stromatoporoids*, and these in some cases had their bases below the top of the Eramosa beds, the structure thus resembling the transition coral reef at Guelph described under Eramosa beds. Brachiopods and gastropods lived in association with the reef builders; *Atrypa reticularis, Whitfieldella nitida?*, and *Pleurotomaria?* being noted.

The most northerly occurrence of Guelph is on the southwestern extremity of Fitzwilliam island. The rock capping the ends of the numerous rock projections and the small islands just off-shore is Guelph. The typical, hummocky, Eramosa beds are exposed on the mainland at the base of the scraggy, thick-bedded Guelph and a very few typical Guelph fossils were found. Among these, *Rhinobolus galtensis* is the most reliable guide to the Guelph. No Guelph strata have been identified on Manitoulin island. Some of the rock at South Baymouth is much like the Guelph, but although the shore was studied both east and west, no Eramosa beds were identified and no Guelph guide fossils were found. For Guelph fossils see table page 000, and Plates XXII to XXVII.

CORRELATION.

The Guelph formation extends into New York state, including, as already stated, the upper 43 feet of the section exposed along the Niagara river and according to Chadwick probably 100 feet of higher beds. The Eramosa beds have been recognized by Chadwick and the author in the barge canal at Rochester and the dolomite above is typically Guelph. This accords with the maps of New York state. As already stated under "Lockport formation," the upper Shelby and the overlying beds may be considered the New York equivalent of the Guelph formation of Ontario. The Racine beds of Wisconsin and Illinois contain, according to Chamberlain[1], a cephalopod fauna very similar to the fauna in the lower Guelph near Wiarton, and also many distinctly Guelph genera and species, such as *Megalomus canadensis*, *Dinobolus Conradi*, and *Trimerella* cf *grandis*. The author, while visiting the more important Wisconsin and Illinois occurrences of the Racine beds in 1914, was impressed with the decided Guelph characters of the Racine, and moreover, accompanied by Professor Stuart Weller of Chicago university, he was able to point out the great similarity of the lower beds exposed in a quarry at the locality south of Chicago known as "Stony Island," to the Eramosa beds of Ontario. The general thin-bedded character of 15 feet of these beds and the vugs of soft bitumen in some lower beds were very suggestive of the general horizon of the Eramosa beds, and the presence of a poor specimen of *Pycnostylus guelphensis* in the upper beds of the quarry was additional evidence that the contact between the Guelph and Niagara formations is exposed here. The general northward dip of the strata would readily allow for the Racine and higher beds occurring above this horizon at Chicago, and northward. More field work is necessary before the Guelph-Niagara problem is cleared up in Wisconsin and Illinois, but in the meantime the author prefers to correlate the Racine and the overlying "Guelph beds" of Chamberlain with the Guelph of Ontario.

Kindle[2] has reported Guelph fossils from limestone at Huntington, Indiana, which according to Foerste[3] overlies the Louisville limestone. Strata of Guelph age are doubtless present. Elsewhere in the United States, few occurrences of strata of undoubted Guelph age are reported.

Pycnostylus guelphensis and *Pycnostylus elegans*, found by Dowling[4] on Ekwan river, west of James bay, probably indicate the presence of Guelph strata in this region. Loose glacial boulders containing fossils suggesting Guelph age were found by Hume north of lake Timiskaming. These probably came from James Bay region. *Pycnostylus guelphensis* was found by Tyrrell[5] on Davis point, lake Manitoba, suggesting uppermost Niagara or Guelph strata at this vicinity. It is altogether probable that with further detailed work, other occurrences of Guelph strata will be found in northern Canada. Twenhofel and Schuchert[6] have correlated the

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[1] Geol. of Wis., vol. II, 1873-77, pp. 374-377.
[2] Ind. Dept., Geol. and Nat. Res , 28th Ann. Rept , 1904, p 408
[3] Ind. Geol. and Nat. Res., 28th Ann. Rept , 1904, pp 34 and 35
[4] Palæozoic fossils, vol. III, pt. IV, p. 247
[5] Palæozoic fossils, vol. III, pt. IV, p 284
[6] Am Jour. Sc., vol. XXVIII, 1909, p. 148

Stonehouse formation of Arisaig, Nova Scotia, with the Guelph, and both with the Ludlow of Europe.

GUELPH SEDIMENTATION.

It is generally believed that Guelph strata were deposited in a somewhat restricted sea of increasing salinity. Thick-shelled forms such as *Trimerella* and *Megalomus* are generally taken as being indicative of high salinity and the restricted areas of known Guelph outcrops suggest narrow sea-ways. Evidence is accumulating, however, in support of Grabau's theory that the Salina was derived largely from erosion of the Guelph and Niagara formations. By a careful study of samples taken from wells east of lake St. Clair, it is seen that there is no indication of an erosion surface anywhere in the Guelph-Niagara dolomites, but that where these are unusually thick, the upper beds have distinctive characters, of colour and hardness. Although this may be due to lenticular deposition, it strongly suggests erosion in pre-Salina time. Although lamellibranchs, brachiopods, and gastropods are the most striking Guelph fossils, coral reefs are now known to be common, and great colonies of crinoids are common in some places. Cephalopods were extremely important during the early stages of the Guelph sedimentation in the region of Bruce peninsula and Wisconsin, and were fairly well represented throughout the period. The closing event of Guelph time appears to have been an emergence and erosion period during which a part of the lower Great Lakes region may have remained a partly enclosed sea.

Distribution of the Guelph Fauna.

Genera and species.	Galt. Upper beds.	Hespeler. Upper beds.	Guelph. 50 ft. up.	Rockwood. Base.	Fergus. Below middle.	Elora. About middle.	Durham. Near top.	Markdale. Below middle.	Zinc prospect. Near Wiarton (Basal).	Fishing islands. Lower.	Stokes bay. Basal beds	Halfway rock. 100 ft. up.	Tobermory. Upper.	Cape Hurd. High up.	Cove and Echo islands. Upper.	Middle island. Middle.	West end Fitzwilliam island. Lower.
Anthozoa.																	
Pycnostylus guelphensis Whiteaves.....	x			x					x				x	x		x	
" elegans Whiteaves......	x															x	
Diplophyllum caespitosum Hall....								x									
Favosites favosus (Goldfuss)									x						?		
Favosites niagarensis (Hall)				?													
Favosites hisingeri Edwards and Haime...	x			x					x	?	x		?			?	?
Halysites catenularia (Linnaeus)			x					x						x		x	
Halysites catenularia microporus (Whitfield).													x				
Annellida.																	
Cornulites arcuatus Conrad..											x						
Brachiopoda.																	
Rhinobolus galtensis (Billings)	w x					w	w				x			x	x		
Trimerella grandis Billings......	x		x		x			x		x							
Stropheodonta profunda (Hall).........									x								
Leptæna rhomboidalis (Wilckens)									x								
Dalmanella elegantula (Dalman)													?				
Anastrophia internascens Hall..													x				
Conchidium occidentale Hall ...	x		x		x						x	x			x	x	x
Pentamerus oblongus Sowerby..							w							x			
Clorinda ventricosa (Hall) ..									x								
Rhynchotreta cuneata americana (Hall)																x	
Camarotœchia (Stegerhynchus) neglecta (Hall													x				
Camarotœchia winiskensis Whiteaves													x				
Wilsonia saffordi (Hall).....													x				
Atrypa reticularis (Linnaeus)									x								
Spirifer radiatus (Sowerby)									x								
Spirifer crispus (Hisinger)													x				
Spirifer eudora (Hall)......	x								?								

Distribution of the Guelph Fauna—Continued.

Genera and species.	Galt. Upper beds.	Hespeler. Upper beds.	Guelph. 50 ft. up.	Rockwood. Base.	Fergus. Below middle.	Elora. About middle.	Durham. Near top.	Markdale. Below middle.	Zinc prospect. Near Wiarton (Basal).	Fishing islands. Lower.	Stokes bay. Basal beds.	Halfway rock. 100 ft. up.	Tobermory. Upper.	Cape Hurd. High up.	Cove and Echo islands. Upper.	Middle island. Middle.	West end Fitzwilliam island. Lower.
Brachiopoda—Con.																	
Whitfieldella nitida (Hall)	x												x				x
Whitfieldella nitida oblata (Hall)													x				
Whitfieldella hyale (Billings)	x												x				
Pelecypoda.																	
Amphicœlia leidyi Hall				x					x								
Megalomus canadensis Hall	x						x				x			x			
Matheria recta (Hall)									x		x						
Mytilarca acutirostra (Hall)									x					x			
Pterinea brisa Hall									x								
Pterinea occidentalis Whiteaves													x				
Anodontopsis concinna Whiteaves	w						w							x			
Gastropoda.																	
Tremanotus alpheus (Hall)									x								
Eccyliomphalus circinatus (Whiteaves)	x																
Euomphalopterus valeria (Billings)	x					x											
Liospira perlata (Hall)	w				nx									x			
Eotomaria galtensis (Billings)	x							x						?			
Cœlocaulus bivittatus (Hall)	x				nx						x		?	x			
Cœlocaulus longispira (Hall)	x		x											x			
Cœlocaulus macrospira (Hall)	w		x										?	x			
Cœlocaulus turritiformis (Hall)	x													x			
T[illegible]e constricta (Whiteaves)							w							x			
S[illegible]tina daphne (Billings)	w													x			
Lophospira hespelerensis (Whiteaves)		w												x			
Lophospira bispiralis (Hall)	w													x			x
Lophospira mylitta (Billings)	x					w											
Euomphalus galtensis Whiteaves	w	w					w							x			

Poleumita crenulata (Whiteaves)							w							x			
Poleumita? sulcata (Hall)	w	w	x														
Pycnomphalus solarioides (Hall)	w										x						
Holopea guelphensis Billings	x																
Conularida.																	
Conularia laqueata Conrad									x								
Cephalopoda.																	
Orthoceras brucensis williams sp. nov													x			?	
[1]Cycloceras? sp.									x					?			
Orthoceras unionense (Worthen)														x			
Dawsonoceras americanum (Foord)	x								x		x						
Kionoceras darwini (Billings)		w					w						x				
Protokionoceras crebescens (Hall)									x								
[2]Sphyridoceras costatum (Hall)		w				w			x								
Sphyridoceras desplainense McChesney	x																
Cyclostomaceras orodes (Billings)		w															?
Malonoceras arcticameratum (Hall)	w												x				
Poterioceras n. sp.									x								
Poterioceras sauridens Clarke and Ruedemann													?				
Trilobita.																	
Arctinurus boltoni (Bigsby)									x								
Calymene niagarensis Hall	w																
Cheirurus niagarensis (Hall)																	?

w—reported by Whiteaves but not found by the author. n near locality named.

[1] This is probably Hall's Orthoceras imbricatum? Pal. N.Y., vol. II, pl 62. Some specimens measure 6 inches in diameter.

[2] Revision by Chadwick.

REVISED LIST OF SPECIES.

The following is Whiteaves[1] list of the fossils of the Guelph formatio of Ontario, with the doubtful species omitted and the generic name corrected according to Bassler's index of Ordovician and Silurian fossil Localities are from Whiteaves' earlier lists.

ANTHOZOA.

Pycnostylus guelphensis, Hespeler, Elora, Durham.
Pycnostylus elegans Whiteaves, Hespeler, Durham.
Favosites hisingeri, Edwards and Haime, Galt, Hespeler, Elora, Durham.
Halysites catenularia, Linnaeus, Guelph, Elora, Hespeler, Durham.
Halysites compactus, Rominger, Galt, Elora.

HYDROMEDUSÆ.

Note. Parks list is given below instead of that given by Whiteaves.

BRACHIOPODA.

Trimerella grandis Billings, Galt, Elora, Hespeler.
Trimerella acuminata Billings, Galt, Elora, Hespeler.
Trimerella ohioensis Meek, Durham.
Trimerella billingsi Dall, Hespeler.
Trimerella dalli Davidson and King, Hespeler.
Rhinobolus galtensis (Billings), Galt, Elora, Durham.
Monomorella prisca Billings, Hespeler, Elora.
Monomorella orbicularis Billings, Hespeler.
Monomorella ovata Whiteaves, Durham.
Monomorella ovata lata, Whiteaves, Durham.
Monomorella durhamensis, Whiteaves, Durham.
Pentamerus oblongus Sowerby, Durham.
Conchidium occidentale Hall, Galt, Guelph, Hespeler, Elora, Durham.
Clorinda ventricosa (Hall), Hespeler, Elora.
Camarotœchia pisa (Hall and Whitfield), Hespeler and Elora.
Atrypa reticularis (Linnaeus), Hespeler.
Spirifer radiatus (Sowerby), Durham, Elora.
Spirifer crispus (Hisinger), Durham.
Whitfieldella hyale (Billings), Galt, Hespeler, Elora.

PELECYPODA.

Megalomus canadensis Hall, Galt, Guelph, Hespeler, Elora, Durham, Bellwood.
Megalomus compressus, Nicholson and Hinde, Hespeler.
Amphicœlia neglecta (McChesney), Elora.
Goniophora crassa Whiteaves, Durham.
Illionia canadensis Billings, Elora and Hespeler.
Illionia ? costulata Whiteaves, Elora and Durham.
Anodontopsis concinna Whiteaves, Galt and Durham.
Prolucina galtensis Whiteaves, Galt, Durham.

GASTROPODA.

Scenella conica Whiteaves, Durham.
Archinacella canadensis (Whiteaves), Hespeler.
Tremanotus angustatus (Hall) = *T. alpheus*? Galt, Guelph, Hespeler.
Euomphalopterus valeria (Billings), Durham, Bellwood.
Euomphalopterus halei (Hall), Durham.
Euomphalopterus elora (Billings), Galt.
Lophospira conradi (Hall), Elora.
Lophospira xanthippe (Billings), Galt.
Lophospira mylitta (Billings), Elora.
Lophospira hespelerensis (Whiteaves), Hespeler.
Lophospira guelphica Whiteaves, Durham.
Loxoplocus solutus (Whiteaves), Hespeler, Elora, Durham.

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[1] Palæozoic fossils, pt. IV, pp. 327-345.

GASTROPODA Con.
Phanerotrema occidens (Hall), Elora.
Liospira perlata (Hall), Galt.
Eotomaria galtensis (Billings), Galt.
Eotomaria durhamensis (Whiteaves), Durham.
Clathrospira deiopeia (Billings), Elora.
Hormotoma whiteavesi Clarke and Ruedemann, Galt, Hespeler, Elora.
Cælocaulus? vitella (Billings), Galt.
Cælocaulus? macrospira (Hall), Galt.
Cælocaulus? bivittatus (Hall), Galt, Hespeler, Elora.
Cælocaulus? longispira (Hall), Galt, Elora, Hespeler, Guelph, Durham.
Cælocaulus? turritiformis (Hall), Galt, Elora, Hespeler, Durham.
Cælocaulus? estella (Billings), Galt.
Turritoma boylei (Nicholson), Elora.
Turritoma constricta (Whiteaves), Durham.
Murchisonia? billingsana Miller, Galt.
Lophospira bispiralis (Hall), Galt.
Pleurotomaria cyclostoma Whiteaves, Durham.
Pleurotomaria townsendii, Durham.
Euomphalus galtensis Whiteaves, Galt, Hespeler, Durham.
Euomphalus inornatus (Whiteaves), Elora, Durham.
Eccyliomphalus circinatus (Whiteaves), Galt, Hespeler, Elora, Durham.
Straparollus hippolyta Billings, Galt.
Straparollina daphne (Billings), Galt.
Poleumita sulcata (Hall), Galt, Hespeler.
Poleumita macrolineata (Whitfield), Elora, Durham.
Poleumita crenulata (Whiteaves), Durham.
Poleumita durhamensis (Whiteaves), Durham.
Poleumita parvula (Whiteaves), Durham.
Codonochilus striatus Whiteaves, Hespeler, Durham.
Pycnomphalus solarioides (Hall), Galt.
Loxonema boydi Hall, Galt.
Holopea harmonia Billings, Galt.
Holopea ? occidentalis Nicholson, Elora.
Subulites compactus Whiteaves, Durham.
Cyrtospira ventricosa (Hall), Galt.

CEPHALOPODA.
Protokionoceras crebescens (Hall), Hespeler, Elora.
Protokionoceras medullare (Hall), Elora.
Orthoceras selwyni Billings, Galt.
Kionoceras cancellatum (Hall), Elora.
Kionoceras darwini (Billings), Hespeler, Durham.
Dawsonoceras americanum (Foord), Hespeler, Elora.
Septameroceras septore (Hall), Elora.
Ascoceras townsendi Whiteaves, Durham.
Maelonoceras arcticameratum (Hall), Galt.
Cyclostomiceras orodes (Billings), Hespeler.
Phragmoceras hector Billings, Hespeler.
Phragmoceras nestor canadense Whiteaves, Hespeler, Elora, Durham.
Phragmocerus parvum Hall and Whitfield, Durham.
Sphyradoceras desplainense (McChesney) "Ontario".
Discoceras graftonense Meek and Worthen, Elora, Hespeler.

CRUSTACEA.
Leperditia balthica guelphica (Jones), Durham, Aboyne.
Leperditia praseolus guelphica Jones, Durham.

TRILOBITA.
Calymene niagarensis Hall, Galt.
Cheirurus niagarensis (Hall), "Ontario".
Illaenus aboynensis Whiteaves, Aboyne.

EURYPTERIDA

Eurypterus (Thylopterus) boylei, Whiteaves, Elora

Stromatoporoids of the Guelph formation in Ontario as given by Parks.[1]

Actinostroma vulcana Parks, Durham.

Clathrodictyon ostiolatum Nicholson. No locality given for Guelph occurrence

Clathrodictyon striatellum D'Orbigny, " at all the typical localities ".

Clathrodictyon fastigiatum Nicholson, Elora, Aboyne, and township of Glenelg.

Labechia durhamensis Parks, " Durham, Galt, Guelph, Elora, and throughout the Guelph of Ontario ".

Labechia minora Parks, Elora, Galt, Durham, Glenroading.

Rosenella glenelgensis Parks, Durham, Elora.

Stromatopora galtensis Dawson, Galt, Hespeler, Elora, Durham.

Stromatopora antiqua Nicholson and Murie, Durham?

Stromatoporella elora Parks, " at all of the well-known localities "

Stromatoporella elora minuta Parks, Durham.

Hermatostroma guelphica Parks, Elora.

CAYUGAN GROUP.

GENERAL DESCRIPTION.

"Cayugan group" is here used to include all the Silurian sediments in Ontario above the top of the Guelph dolomite. Thus in the Buffalo region, the formations included are, as recognized by Bassler[2], the Salina (represented by the Camillus shale), the Bertie waterlime, and the Akron dolomite, the latter correlated with the Cobleskill of eastern New York. In the Detroit River region the Salina and the Bass Island series are included in the Cayugan group. The Camillus shale division of the Salina is well marked in this western region and it is probable, as will be seen below that the Bertie and Akron dolomites of the east are to be correlated with the Raisin River and the Put-in-Bay dolomites of the Bass Island series, and consequently, contrary to former usage, this series belongs in the Cayugan group.

The lack of outcrops and good sections is the principal difficulty met with in working out the stratigraphy and correlation of the Cayugan formations. This difficulty is illustrated by the scattered occurrence of outcrops as shown on Map 1715.

SALINA FORMATION.

Description.

The Salina, as its name implies, is the salt and gypsum-bearing formation of New York state and Ontario. The deposits of Salina age represent special conditions of sedimentation, which according to Grabau and O'Connell, are probably those of an interior basin, to which the Atlantic ocean gradually gained freer access until the commencement of the emergence of the continent as a whole, which closed the Silurian period.

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[1] University of Toronto studies, Geol. ser. No. 4, 1917.

[2] U. S. Nat. Mus., Bull. 92, vol. II, 1915, p[illegible]

Camillus Shale Member.

Description. The Camillus shale is the lowest member of the Salina formation of Ontario; it rests unconformably on the Guelph dolomite and is overlain conformably by the Bertie waterlime in the east and the Bass Island series in the west.

Essentially a grey or green shale, this member contains also beds of argillaceous dolomite, large deposits of gypsum in the valley of Grand river between Paris and the vicinity of Cayuga, and extensive salt deposits in parts of New York state and in the area adjacent to lake Huron from Kincardine south to lake St. Clair and near Windsor.

The characters of this formation are illustrated in the following descriptions of sections, and Figure 4.

A drill core from north Buffalo as interpreted by Grabau gives a section of the Camillus, 387 feet thick, which includes, in ascending order: gypsum and shale, mottled and in streaks, 290 feet; compact shale, 3 feet; shale and limestone, 4 feet; dark limestone, 2 feet; drab shale and thin gypsum, 58 feet; shale and gypsum, 7 feet; white gypsum, 4 feet; shale, 1 foot; white gypsum, 12 feet; shale, 2 feet; pure white gypsum, 4 feet; overlain by the Bertie waterlime. The beds penetrated in the gypsum mine of the Alabastine Company at Caledonia are, in ascending order, as follows: 3 inches of gypsum; 4 feet of dark grey, impure dolomite; 3 feet of fine white gypsum; 10 feet of brown dolomite containing some gypsum; 7 feet of gypsum with thin, limy partings and limy accumulations; 4 feet of mixed dolomite and gypsum; 3 feet of impure dolomite; 6 feet of gypsum mixed with dolomite. The weathered exposures of shale along Grand river are grey-green in colour and generally soft and fissile.

The upper Camillus shales are represented by pea-green to grey, hackly shale in outcrops along Niagara river 100 yards north of the international bridge at Bridgeburg, Ont. Indications of gypsum are seen a little farther down stream. The best of the northern sections is that below the bridge over the branch of Saugeen river at Ayton. In ascending order the section is: 4 feet of hard, firm shale; 4 feet of hard, uneven dolomite, breaking with conchoidal fracture; 4 feet of hard, thin-bedded, buff dolomite with bituminous partings; 2 feet of hard, brown dolomite; 7 feet of firm, buff shales and thin dolomites; 11 feet of thin, fissile, green-weathering shale; 4 feet of light buff dolomite full of minute cavities.

Another section in the bank of a branch of the Saugeen river, on lot 19, concession VI, Normanby township, Grey county, is as follows: 3 feet shale; 10 feet hard, grey dolomite; 12 feet soft shale; 15 feet of nodular, green shale; 2 feet green shale containing red patches, probably originally all red; 2 feet of buff dolomite (calcilutite); 2 feet of green-grey, impure dolomite. This is the only locality known to the author where red shale occurs in a Camillus shale outcrop. The red shale was probably more extensive than is shown, the red beds being largely deoxidized by surface water containing humic acid derived from plants.

In the west bank of Saugeen river below Walkerton, at the crossing of the line between concessions III and IV, about 16 feet of nodular green shale is overlain by 20 feet of buff dolomite, belonging to the Bertie-Akron division.

The total thickness of the Camillus shale at Delhi, Norfolk county, is 310 feet; near London the thickness, including 170 feet of salt, is 750 feet; in Dover township, near lake St. Clair, the thickness varies between 550 and 745 feet, the least thickness being where the underlying Guelph dolomite is thickest and *vice versa*.

The varying thickness of the shale and the irregularities in the underlying formation are suggestive of warping, uplift, and erosion at the end of Guelph time, as described by Grabau.

Origin of Camillus Shale.

Grabau has made a careful study of the origin of the Camillus shale, with the contained salt and gypsum, and concludes[1]:

"At the close of the Niagara period, there appears to have been an elevation of the continent which converted . . . . . the greater part of the interior Siluric sea into a vast partially or entirely enclosed basin. This elevation appears to have been accompanied by climatic desiccation which brought about a rapid evaporation of the waters and a consequent increase in salinity. Thus this great interior water body was changed from a richly peopled mediterranean, to a lifeless body of intensely saline water, a veritable Dead sea. . . . . The clastic strata of the Salina series were probably derived from the destruction of the sediments which were formed during the early periods of the Siluric and during preceding periods . . . . . they may in fact be regarded as consolidated argillo-calcareous muds derived from older limestones and shales."

The salt deposits of New York state and the much greater deposits of the Michigan basin, whose eastern rim includes the Lake Huron-Lake St. Clair region of Ontario, were evidently the result of extreme desiccation in isolated basins. Deposition of gypsum took place as its saturation point was reached, and later the salt was deposited. These depositions alternated, responding to more or less periodic inflows of water and excess of evaporation. It has been determined that salt comprises about 77·8 per cent of the solids contained in sea water and calcium sulphate comprises 3·6 per cent. The latter, however, begins to precipitate when 80 per cent of the water is evaporated, salt not being deposited until 93 per cent of the water is evaporated. It is clear that in cases of extreme evaporation the deposits of calcium sulphate (gypsum and anhydrite), because of its small content in sea water, will form very insignificant deposits compared with that of the salt. If total desiccation took place the deposits would be in the ratio of 3·6 parts by weight of anhydrite to 77·8 parts by weight of salt. If just sufficient water were added from time to time to the evaporating basin to prevent desiccation reaching the stage necessary to deposit salt, calcium sulphate would continue to be deposited and important beds of anhydrite and gypsum would be formed, as was the case in parts of New York state and the Paris-Cayuga section of the Grand valley in Ontario.

BERTIE WATERLIME FORMATION.

Description.

The Bertie waterlime formation is composed of thin-bedded dolomites, jointed waterlimes, and interbedded, dark grey shale. The lower contact is transitional from the Camillus shale, and the upper contact with the Akron dolomite is marked by a lithologic change, which is not everywhere easily detected. As described by Grabau, the Bertie is represented in a drill core from north Buffalo, in ascending order, as follows: 13 feet of shale and cement rock at the base, 5 feet of fairly pure cement rock, and 25 feet of shale and cement rock at the top.

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[1] N. Y. State Mus. Bull. 45, pp. 127-8.

Chadwick[1] has divided the upper part of the Cayugan group in western New York as follows (all but the Akron are divisions of the Bertie formation):

	Feet
Akron dolomite (Grabau), subcrystalline, grey to brownish, with *Cyathophyllum hydraulicum*	12 or less
Buffalo cement bed carrying eurypterids	6
Scajaquada dark shales and blocky waterlimes, at base the Bridgeburg horizon with eurypterids	8
Falkirk dolomite, brownish and bituminous, below massive and often producing waterfalls; a marine fauna, but eurypterids at base.	30
Oatka beds, dark grey and shaly, with a blocky waterlime at base carrying eurypterids	20 or less

In the criticism of this memoir [illegible] Chadwick[1] has omitted the term Buffalo and used in its place Williamsville.

The shales and waterlime along the [illegible] Grand Trunk tracks at Bridgeburg, probably belong to the upper part of the Bertie (Scajaquada including Bridgeburg and top of Falkirk [illegible]) and the shale just south of the international bridge is probably [illegible] base of the Bertie division.

At a quarry north of Ridgeway, on [illegible] concession X, Bertie township, Welland county, the following partial section of Bertie beds occurs: 7 feet of thinly laminated, brown dolomite with bituminous partings at the base of the section (Falkirk); 4 feet of light grey, jointed dolomites (Bridgeburg); 6 feet of hard, slate-grey shale, with *Eurypterid* fragments, at the top (Scajaquada); 5 feet of waterlime (Williamsville) overlain by 6 feet of Akron dolomite.

About one-third of a mile due west of Ridgemount at the road forks, heavy beds of dolomite (Falkirk) contain numerous specimens of *Whitfieldella sulcata* and *ostracoda*. These beds overlie about 10 feet of thinner beds which are probably lower Bertie (Scajaquada). Along the "Ridge road" south of the above-mentioned exposure the base of the Akron is about 13 feet below the Oriskany sandstone [illegible] being the thickest Akron section known in the vicinity.

At the Municipal quarry, southeast of Byng and on the west side of Grand river, not far from Dunnville, the exposed Bertie section consists in ascending order, of: 7½ feet of hard, siliceous [illegible] shale with dark partings; one-half foot of hard, nodular shale; [illegible] feet of massive, hard, light grey, fine-grained dolomite (calcilutite) containing *Schuchertella hydraulica?* near the top; 2 feet of hard, grey shale; [illegible] 7 feet of laminated and mottled, blocky dolomite (magnesian calcilutite, probably Akron) overlain above a decided erosion unconformity, by lenses of Oriskany sandstone.

From Dunnville west and north few exposures of Cayugan rock occur and the Bertie and Akron beds have not been differentiated. The exposures will be described under Akron dolomite. It seems probable that in Kent and Essex counties the extension of the Berti waterlime is to be correlated in age with the Put-in-Bay dolomite and the underlying Tymochtee shale and Greenfield dolomite (see below under Bass Island series

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[1] Bull. Geol. Soc. Am., No. I, vol. 28, p. 173.

Fauna.

The muddy, calcareous Bertie sediments contain a rich *Eurypteru* fauna, but very little else. As given by Ruedemann the fauna of the Bertie (Williamsville) is as follows:

Inocaulis vanuxemi (Grote and Pitt
Lingula testatrix Ruedemann
Diaphorostoma sp.
Hercynella patelliformis O'Connell
H. buffaloensis O'Connell
Hormotoma gregaria Ruedemann.
Orthoceras vicinus Ruedemann
Phragmoceras accola Ruedemann.

Clarke and Ruedemann list the following eurypterids[1] from th Bertie waterlime.

Dolichopterus macrocheirus Hall
D. siluriceps Clarke and Ruedemann
D. ? testudineus " "
Eurypterus dekayi Hall
E. lacustris Hall.
E. lacustris var. *pachycheirus* Hall
E. pustulosus Hall
[2]*E. remipes* Dekay.
E. scorpionis Grote and Pitt.
Pterygotus buffaloensis Pohlman.
P. cobbi Hall var. *juvenis* Clarke and Ruedemann
P. grandis (Pohlman).
P. macrophthalmus Hall.

Chadwick by correspondence gives the following as occurring in t Falkirk division of the Bertie:

[3]*Whitfieldella sulcata* (Vanuxem).
Gomphoceras osculum Ruedemann.
Leperditia cf *scalaris* (Jones).

Origin of the Bertie Waterlime.

According to Miss O'Connell, who has made a special study of the Bertie waterlime from the standpoint of " the habitat of the Eurypterida the deposits at Buffalo and at Herkimer, New York, both of which ca eurypterid faunas, are best explained as deltas of low-lying, meanderi rivers flowing from the north. The marine organisms are supposed have been transported upstream by tidal action. On page 117, we re " The only available source of the lime in the Bertie is from the m derived by the erosion of an older magnesian limestone, the Niaga or in some cases, perhaps, the Trenton. Where the Bertie is eurypterid-bearing, the rock was evidently deposited above sea-level, as a river flood-plain and subaerial delta deposit. Southward and laterally the subaqueous part of the delta carries few or no eurypterid remains, but more marine organisms. That the Bertie eurypterids lived in the river is thus indicated . . . . ."

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[1] N.Y. State, Mem. 14, vol. I, 1912, p. 431
[2] See Plate XXVII
[3] See Plate XXVII.
[4] Bull. Buffalo Soc. Nat. Sc., 1916

An entirely different view of the case is taken by Ruedemann[1] who, after discussing O'Connell's arguments and refuting the suggestion that the eurypterid fragments had drifted into their present position, sums up as follows:

"The *Buthotrephis* has been proved in this paper to be a good sessile graptolite of the genus *Inocaulis*. It occurs in the waterlime in splendidly preserved colonial stocks, which cannot have drifted any distance. The *Lingulas* and *Hormotoma* occur in certain layers in such immense quantities that they are certainly in their proper surroundings where found . . . . At any rate there is not in the whole assemblage of the Bertie waterlime a single genus that could be considered as indicative of a freshwater fauna, and all these marine forms are found on the same slabs with the eurypterids, so that an alternation of marine and freshwater conditions cannot be assumed either."

The above summarizes the divergent opinions as to the probable origin of the typical Bertie beds where recognized by faunal evidence. Elsewhere, they have been determined by stratigraphic and lithologic evidence and appear to be sediments derived from older rocks laid down in a shallow sea. The water was probably too salty and too muddy to favour the development of diversified life.

AKRON (DOLOMITE) FORMATION.

Description.

In the cement quarry at Buffalo about 7 feet of light grey, mottled, somewhat nodular dolomite rests on the Bertie waterlime, and is terminated above by a decided erosion surface upon which lie lenses of Oriskany sandstone and beds of Onondaga limestone. This is the Akron dolomite. Small cavities are common in the Akron, which has in part wavy bedding, and contains *Cyathophyllum hydraulicum* and *Schuchertella hydraulica* (see below).

The Akron dolomite was named by Grabau[2] from its occurrence at Akron Falls, east of Falkirk, New York. Here, as seen by the author, the Akron, which has wavy bedding, is about 5 feet thick, light grey in colour, somewhat nodular, fine-grained, and weathers into a pitted surface. The underlying bed of Bertie waterlime was formerly burnt to natural rock cement. The overlying formation is the Onondaga, but the contact is seen and the disconformity is not evident.

A good section of the Akron dolomite occurs at the quarry near the schoolhouse north of Ridgeway, lot 1, concession X, Bertie township, Welland county. Here the total thickness is about 7 feet. The characters are about as at Buffalo and *Schuchertella hydraulica* and *Cyathophyllum*

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[1] Ibid, p. 115.

[2] Bull. Geol. Soc. Am., vol. 19, p. 544

hydraulicum are found. A similar section occurs at a quarry on lot 8, concession XIII, Bertie, where Onondaga limestone overlies the Akron.

At Byng near Dunnville, in the Municipal road-metal quarry, 5 to 7 feet of Akron dolomite is terminated above by an irregular erosion surface upon which lie lenses of Oriskany sandstone. The Akron consists of thin-bedded, blocky calcilutite of mottled grey colour, and rests on hard, grey shale. At the John Weber quarry near Byng, on lot 16, concession I south, Dunn township, the Akron appears to be 15 feet or more thick, but the boundary between the Akron and the Bertie is not easily drawn.

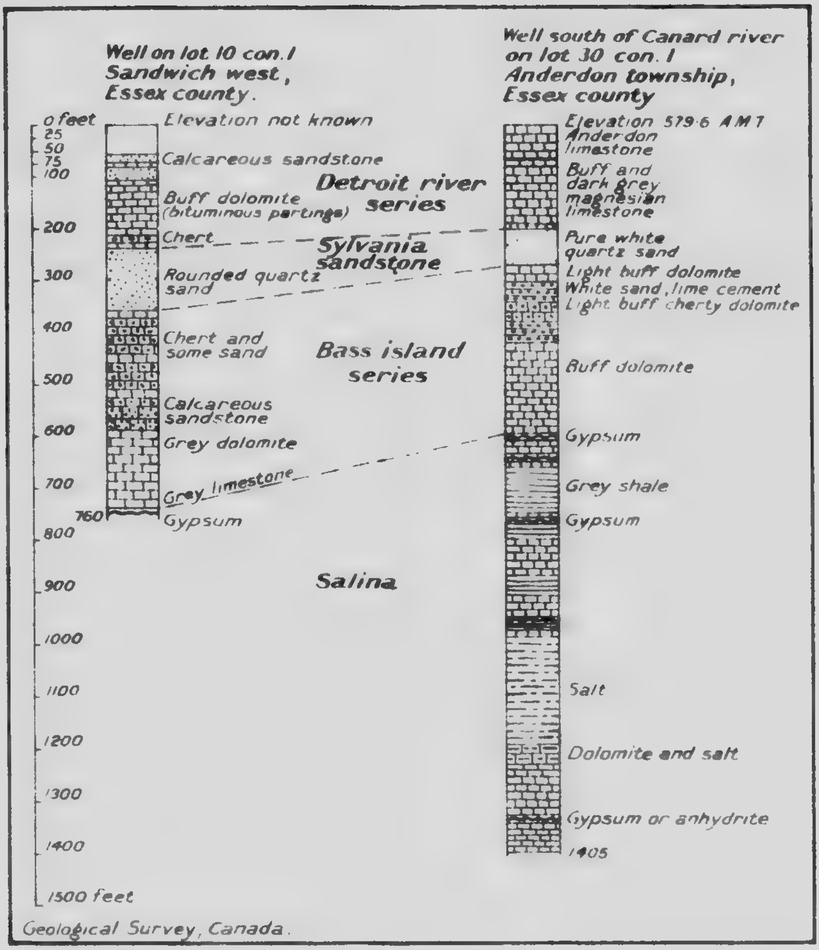
The outcrops west of Dunnville, not easily divided into Akron and Bertie, are described below. As will be seen on Maps 1714 and 1715, a number of outcrops of the upper Cayugan dolomites occur in the vicinity of Cayuga west of Grand river. The best and most representative section is that north of the road in the river bank, on the fronts of lots 3, 4, and 5, River road, Cayuga, South, township, Haldimand county. In ascending order the section is: Camillus shale consisting of 12 feet of light grey, thin-bedded dolomite, and 8 feet of grey shale including a 1-foot bed of waterlime near the top; Bertie-Akron consisting of a 3-foot massive bed of light grey dolomite, and 20 feet of light grey, blocky dolomite, overlain by cherty Onondaga dolomite.

At Springvale, an 8-foot section is exposed in a quarry, the lower 5 feet of the beds being thin and blocky and the upper 3 feet being one massive bed. The colour is light buff. This stone was burnt for lime by Mr. Winger, who says that it burnt to a strong, white lime and that it was used in the building of the convent at Niagara Falls, New York. The waterlime bed is said to lie just below the exposed rock of the quarry. A short distance southwest of Springvale, the Springvale (Devonian) sandstone occurs, limiting the Cayugan above. Other small exposures similar to the above occur south of Springvale.

About 2 miles east of Hagersville, at a cut on the Michigan Central railway near where two roads cross, 8 feet of thin-bedded, jointed, cream-coloured, fine-grained dolomite is terminated upward by an erosion surface on which rests cherty Onondaga limestone.

At Innerkip, just south of the station, stone was formerly taken from a quarry and burnt to quicklime by the aid of natural gas which was struck on the quarry site. The face of rock now exposed above water is 8 feet high, consisting of light buff, fine-grained dolomite. The lowest bed, which is very fine-grained and breaks with conchoidal fracture, is 3 feet thick and is overlain by a thin bed of green, glauconitic, dolomitic very fine-grained sandstone, 1½ inches or less in thickness. The beds above are thinner and weather into nodules. The main sandstone bed lies on an irregular erosion surface, and streaks of sand occur 6 inches lower down and also in cracks at a slightly lower horizon. The lime burnt from the stone in this quarry was grey.

Two specimens of *Whifieldella prosseri* Grabau were found just above the sandstone. These consist of moulds of the interior of the shell and the sinus in the pedicle valve is not well marked. The specimens compare closely in size and other characters with Grabau's illustrations and descriptions. Had the fossils occurred below the sandstone it might be assumed that these beds were the top of the Silurian. The sand is probably, how-



Geological Survey, Canada.

Figure 5. Diagram showing formations near Detroit river as indicated by two wells drilled by the Solvay Process Company.

To accompany Memoir by M Y Williams

ever, a forerunner of the Sylvania which has been deposited on a limestone surface scoured by shore currents during a partial retreat of the sea. The presence of *Whifieldella prosseri* in these beds correlates them with the Raisin River dolomite of Ohio and Michigan. This outcrop forms a link between the Akron dolomite and the Raisin River dolomite, which as explained below are thought to be of the same age.

As mentioned above under "Camilius shale", about 6 feet of fine-grained, cream-coloured dolomite is exposed in the bed of a small tributary entering Saugeen river from the west just north of Walkerton. Along the Canadian Pacific railway, just south of Walkerton, buff dolomite with bituminous partings contains *Leperditias* resembling *altoides* Grabau and *Whitfieldella sulcata* (Vanuxem)? In the east bank of the Saugeen, at the crossing of the boundary between concessions III and IV, Brant county, about 20 feet of buff dolomite, fairly thick-bedded in the lower third and thinner-bedded above, overlies nodular, green shale. The dolomite is dense and fine-grained, suggesting the characters of lithographic stone.

The best northern section of the Bertie-Akron is that exposed along a small unmapped tributary entering Saugeen river from the west just south of the line between concessions VII and VIII, Brant township, and about 2½ miles north of Walkerton. The section is as follows, in ascending order from the bed of the Saugeen up: 4 feet of buff dolomite in 1 to 2-inch beds; a covered interval of about 3 feet; 5 feet of thin-bedded, buff dolomite; 10 feet of buff dolomite in 1 to 2-foot beds, 4-foot massive bed, fine-grained and hard, formerly quarried and burnt to grey lime at nearby kilns; 1 foot of soft, yellow-weathering shale; 12 feet of dolomite in beds 1 to 2 feet thick. Small exposures of rock referred to the Bertie-Akron division occur on the Teeswater river about 1 mile below Pinkerton, and on a tributary of the Teeswater one-half mile east of Bradley.

Fauna.

The fossils contained in the Akron dolomite of New York as given by Grabau[1] and corrected by Chadwick, are as follows:

PLANTS. *Nematophycus crassus* (Penhallow) horizon doubtful.

ANTHOZOA. *Cyathophyllum hydraulicum* Simpson.

BRACHIOPODA. *Schuchertella interstriata* (Hall).
Spirifer eriensis (Grabau)?

BASS ISLAND SERIES.

Definition and General Description.

Grabau has applied the name Bass Island series to the dolomites and shales of Ohio and Michigan, lying between the top of the Camillus shale as recognized in that region and the Sylvania sandstone. His subdivisions are, in ascending order: the Greenfield dolomite; Tymochtee shales; Put-in-Bay dolomite; and Raisin River dolomite. These divisions were studied at widely separated localities and the boundaries and relations are hence not very well known. As seen in Figure 5, the thickness of the

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[1] N.Y. Mus., Mem. 45, pp. 233-237.

Bass Island series along Detroit river is from 330 to 375 feet. The following descriptions are from Grabau and Sherzer[1].

The Greenfield dolomite is mostly thin-bedded, drab-coloured on fresh fractures, and oxidizes to a yellowish shade. Its greatest thicknes at Greenfield, Ohio, is 100 feet. The principal fossils of the Greenfield dolomite are:

Schuchertella hydraulica (Whitfield).
Hindella (?) (*Greenfieldia*) *whitfieldi* Grabau.
Hindella (?) (*Greenfieldia*) *rostralis* Grabau.
Pentamerus pesovis Whitfield ?
(horizon doubtful).
Whitfieldella subsulcata Grabau.
Whitfieldella rotundata (Whitfield).
Rhynchospira praeformosa Grabau.
Camarotœchia hydraulica (Whitfield).
Leperditia ohioensis Bassler.
Leperditia angulifera Whitfield.
Sphaerococcites? glomeratus Grabau.

At their typical exposure, the Tymochtee shales are 24 feet thick an consist of tough, thin-bedded, bituminous shale. The contained fossil are *Leperditia alta* and a species of ?*Modiolopsis.*

The Put-in-Bay dolomite consists of more than 60 feet of massive brecciated, dolomites interbedded with thin-bedded dolomites. Th colour ranges from blue to grey and cream. The commonest fossils foun in the upper beds are *Goniophora dubia* (Hall) and *Spirifer ohioensi* (Grabau). The less common species are *Leperditia alta* (Conrad) an *Eurypterus micropthalmus*. The beds of this division are not known i contact with the Tymochtee shales or the Raisin River dolomite and thei position and extent are hence somewhat problematical.

The Raisin River dolomite consists of grey-drab, magnesian lutites and oolites and is about 200 feet thick. The following fossils w obtained between 87 and 138 feet below the Sylvania sandstone in t Detroit salt shaft.

PLANTÆ.	*Sphaerococcites? glomeratus* Grabau.
BRACHIOPODA.	*Pholidops* cf *ovata* Hall.
	Schuchertella hydraulica (Whitfield).
	Schuchertella interstriata (Hall)
	Whitfieldella prosseri Grabau.
	Camarotœchia sp.
PELECYPODA.	*Pterinea lanii* Grabau.
	Goniophora dubia (Hall).
	Tellinomya sp.
	Modiomorpha sp.
GASTROPODA.	*Ectomaria minuta* (Hall).
	Holopea three sp.
	Loxonema sp.
CEPHALOPODA.	*Cyclostomiceras orodes* (Billings).
OSTRACODA.	*Klœdenia monroensis* Grabau.

Occurrences.

No outcrops of upper Cayugan rocks that can be directly correlat with the Bass Island series occur in Ontario, excepting the outcrop

[1] Mich. Geol. and Biol. Surv., Pub. No. 2, geol. ser. 1, 1910, p. 29-40

Innerkip described above under Akron dolomite, and rocks forming the Canadian islands and reefs west of Pelee island. These islands are only a short distance from Bass islands, from whence the series name was obtained, and are described below from a brief study made of them by the author.

Hen island, which is nearest Pelee island, is a flat, park-like island of 4 or 5 acres extent, fitted out with club houses, a dock, etc. Its highest elevation is between 10 and 15 feet above the lake. Fine trees consisting of elm, maple, and hackberry furnish abundant shade. As might be expected from its exposed position, Hen island is underlain by resistant rock—a dense, fine-grained dolomite The best exposure is on the northwest side where the following section is exposed in ascending order: 3 feet of massive, uneven weathering, fine-grained, buff dolomite containing numerous specimens of *Whitfieldella prosseri* Grabau and a few specimens of *Rhynchospira præformosa* Grabau?; 1 foot of light grey, laminated dolomite; 2 feet of massive, buff, fine-grained dolomite; 2 feet of massive, light brown dolomite containing 1 inch or more of sand mingled with the dolomite near its base. This sand, which makes up about half the material of the thin bed, weathers into relief, and shows the characters of the Sylvania sand. At the top of the section is a 2-foot bed of dense, fine-grained dolomite containing vugs of celestite (?) and weathering into a scraggy rock with numerous irregular spaces. The strike of the bedding at this locality is about east, 20 degrees south and dip south 6 degrees. Thus the strata exposed at the extreme eastern end of the island are lower in the section than those just described, about 5 feet more of the lower massive bed being exposed.

Big and Little Chicken islands are mere reefs washed by the waves except in the calmest weather.

East Sister, the largest of the group of islands, is low and flat and was formerly cultivated. Club houses are situated near the southeast end and peach trees planted some time before were struggling with weeds in September, 1914. A fringe of hackberry, maple, and wild grape surrounds the island. A gravel bar about 5 feet high is piled up along the south side, the gravel being in general under 2 inches in diameter and consisting of about 75 per cent dolomite and 25 per cent granite, etc.

At the western end of the island a small syncline occurs with direction of axis about north 40 degrees west. The dips toward the middle are about 2 to 3 degrees and the width of the syncline is only about 50 feet. Exposures to the east show buff dolomite overlying oölitic dolomite which occupies troughs 2 feet wide and 1 foot deep in the underlying rock, along an exposed length of 4 feet. This oölite corresponds closely with the description of the Raisin River oölites given by Grabau.[1] Farther west, thin-bedded, grey dolomite underlies oölitic dolomite about 2 feet in thickness. Below, to the east, dark massive rock is exposed containing numerous specimens of *Whitfieldella prosseri* Grabau and a few specimens (one observed) of *Spirifer ohioensis* Grabau. The extreme eastern end of the island consists of a dome of rock, about 50 feet wide, extending nearly east and west. Glacial striæ here run about 5 degrees north of west. Probably not more than 25 feet of strata are exposed on the island, the exposures at the west end representing the top and those at the east end representing the bottom of the section.

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[1] Grabau and Sherzer, p. 56.

North Harbour, the smallest of the islands, is about 300 yards long by 50 yards wide, and is covered with hackberry and maple trees. The shores are rocky except at the east end where the rock is covered with gravel. About 6 feet of beds are represented on the island, consisting of: light grey dolomite in 6-inch beds extending below the water; 2 feet of arenaceous dolomite with an irregular upper surface; and a massive 3-foot bed of dense, grey dolomite at the top. The remains of a fossil were seen in the upper bed, but no identification could be made. The beds lie nearly flat. The water on the south side is deep to the shore, that on the north side being shallower. Glacial striæ on the north side run about 8 degrees north of west.

Middle Sister island is well wooded with maple, hackberry, and elm and has long been used as a fishing station. At the north end, and on the southwest, the rock is overlain by gravel. The best rock exposures are on the northwest side where a 10-foot section occurs, consisting of 6 feet of thin-bedded, buff dolomite and 4 feet of fine-grained, dense, buff grey dolomite at the top, which is irregularly bedded and contains fragments of *Whitfieldella prosseri* Grabau. Strata at the southwest end strike east 20 degrees south and dip south 6 degrees. Glacial striæ at the southwest end run due west.

From the fossil evidence, there is no doubt of the Cayugan age of the dolomites of the islands described and from the presence of a sand streak in the dolomite of Hen island, it seems probable that the Sylvania sandstone itself was not much higher up. The close similarity in the lithology and fossils of all the islands suggests strongly that the same horizons are exposed on them. This supposition is further supported by the fact that the islands are probably on the strike of the same beds as a slight bending to the south of the western extension of the strike of the beds of the more easterly islands would include Middle Sister island. In other words, these islands are a remnant of the upturned edges of strata which alone in the whole formation were hard enough to resist glacial, wave, and all other erosion sufficiently to remain above the lake-level to the present time.

Of the fossils, *Spirifer ohioensis* is found in the upper part of the Put-in-Bay dolomite at Peach point, Put-in-Bay island; *Whitfieldella prosseri* is characteristic of the Raisin River dolomite, being found throughout the section of this formation in the Detroit salt shaft, and also at New Port, and Monroe, Michigan, and at Peach point, Put-in-Bay, where it is thought to mark the base of the Raisin River dolomite. *Rhynchospira præformosa*, doubtfully determined for Hen island, is described from the Greenfield dolomite. The positive evidence thus points definitely to the Raisin River age and correlation of the strata exposed on the islands. The oölite found on East Sister island is apparently identical with the Raisin River oölites described by Grabau and is a further indication of identity with the Raisin River dolomite. The sandstone of Hen island suggests that the beds are near the base of the Sylvania sandstone and hence near the top of the Raisin River formation. *Spirifer ohioensis*, on the other hand, suggests correlation with the lower portion of the Raisin River dolomite, for this species is found in the beds at Peach point which Grabau placed at the top of the Put-in-Bay dolomite, but which may belong to the base of the Raisin River, as *Whitfieldella prosseri* is reported from the same place and th latter is exclusively a Raisin River species. If Hen island represents strat near the top of the Raisin River dolomite, there is plenty of room for th

Detroit River series, known to be thin east of lake St. Clair, to outcrop between this island and Pelee island which consists of rocks of Onondaga age. It may be noted that the distance here is less than that between Put-in-Bay island and Middle island (Onondaga), within which distance the Raisin River as well as the Detroit River series must outcrop.

Correlation of Bertie and Akron Formations with the Bass Island Series.

It has been shown above that Raisin River dolomite outcrops at Innerkip, and this locality is a connecting link between the regions occupied by well-defined Akron and Bertie dolomites and the Bass Island series. Although positive proof is lacking, there is a strong indication that the Akron and the Raisin River dolomites are to be correlated at least in part. The presence of *Schuchertella interstriata* in both formations supports this correlation and the somewhat close relationship of the *Whitfieldellas* of these formations is suggestive. Again, the presence of *Leperditia alta* (Conrad) and *Eurypterus micropthalmus* Hall, in the upper beds of Put-in-Bay (which may yet have to be considered basal Raisin River), are clear evidence of Manlius affinities, since both these species occur in the Manlius of New York.

If the Akron is to be correlated with the Raisin River formation, including the upper beds in Put-in-Bay island, it would be natural to expect that the Bertie might be correlated with the Put-in-Bay dolomite if this lies just below, and the 12 feet of waterlime found in the lower third of the section at Put-in-Bay is very suggestive of the Bertie beds. There is a strong probability that the Akron dolomite of New York, as stated above, is to be correlated with the Raisin River dolomite, and that the Bertie waterlime may be correlated in part with the Put-in-Bay dolomite (if the latter has the relations assigned to it by Grabau) and in part with the Tymochtee shale and Greenfield dolomite. That the basin of sedimentation in Michigan and Ohio was deeper than that in New York, is shown by the thicker dolomite deposits.

Professor G. H. Chadwick disagrees with the above conclusions and offers the following alternative correlation.

Believing that the Put-in-Bay dolomite is above the Raisin River dolomite rather than below it as described by Grabau, and accepting the author's correlation of the Akron dolomite with the Raisin River dolomite, he correlates the Put-in-Bay dolomite with the lower Manlius (= Cobleskill); the Tymochtee shale with the upper Bertie (his Williamsville and Scajaquada divisions, and the Greenfield dolomite with the lower Bertie) (his Falkirk and perhaps Oatka divisions).

His table is as follows:

Detroit region.	Western New York.	
Put-in-Bay dolomite	Lower Manlius=Cobleskill dolomite.	
Raisin River dolomite	?"Roundout" waterlime	
	Akron dolomite.	
Tymochtee shale	Williamsville waterlime and shale.	Bertie.
	Scajaquada limy shale.	
Greenfield dolomite	Falkirk dolomite	
	?Oatka dolomite.	
	Salina formation—shale, etc.	

This contention is supported by the presence of the Manlius species. *Leperditia alta*, and *Eurypterus microthalmus* in the upper beds on Put-in-Bay island, but on the other hand *Spirifer ohioensis* and *Whitfieldella prosseri*, as shown above, suggest the correlation of these beds with the lower part of the Raisin River dolomite.

It appears evident that no final correlation can be made until the relative position of the Raisin River and the Put-in-Bay formations is decided by additional field work, preferably in Ohio and Michigan.

GENERAL CORRELATION OF CAYUGAN GROUP.

The Cayugan members present in Ontario are much more limited in numbers than are those of central New York state, where the Pittsford shale and the Vernon shale are present below the Camillus shale and higher formations occur above the Akron dolomite. Bassler[1] correlates the Salina shales in a general way with the High Falls shale of eastern New York, the Longwood shale of New Jersey, and the McKenzie formation of Pennsylvania, Maryland, and Virginia. He correlates the Decatu limestone of west Tennessee with the lower Salina shales and the Leclaire (lower Gower) of Iowa and Minnesota and the lower part of the Waubake limestone of eastern Wisconsin with the upper Salina shales (Camillus In the upper Cayugan division Bassler includes, in ascending order: the Bloomsburg sandstone, the Wills Creek limestone, the Tonoloway limestone, and the Bossardville limestone, of Pennsylvania, Maryland, and Virginia, the Bertie and Akron being given as in part equivalent to the lower three divisions; the Sneedville limestone of Tennessee, given as in part equivalent to the Manlius of New York; the Kokomo limestone of Ohio west of Cincinnati, this being given as nearly the equivalent of the Bertie-Akron; and the Hillsboro sandstone and the Greenfield dolomite of southern Ohio and eastern Kentucky, given as representing the Bloomsburg sandstone and a part of the Manlius limestone respectively. The correlation of the Greenfield dolomite with the lower Manlius cannot stand if the writer's contention is correct, that the Greenfield dolom is probably the equivalent of the lower part of the Bertie formation Bassler correlates the Anamosa (upper Gower) of Iowa and Minnesota and the upper Waubakee limestone of eastern Wisconsin with the Bloomsburg sandstone or lowest part of the upper Cayugan. He also correlates the lower Cayugan with the upper part of the Stonehouse formation Nova Scotia, and the whole Cayugan group with the Ludlow group England, Scotland, and Wales. Twenhofel correlates the Stonehouse with the Ludlow of Europe, but with the Guelph of America.

There is reason to believe that formations of Cayugan age will found in northern and western Canada when more detailed stratigra is done.

CAYUGAN HISTORY.

The diastrophism or regional movements which terminated Guelph sedimentation, caused the sea to withdraw from the greater part of North America, but left the following water bodies: a basin which included the present Great Lakes exclusive of lake Superior, and a portion of the Ap lachian region as far south as southern Virginia; an arm of the sea including part of Newfoundland, Anticosti island, and Gaspe peninsula; and probably areas in Florida, Alabama, Georgia, California, and southeastern Alaska which were connected with the open seas[1]. Unlike the other regions, the Great Lakes[1]—Appalachian basin was practically isolated from the sea during the deposition of the Camillus shale and particularly during the extreme desiccation which caused the precipitation of the salt beds. At this period the marginal uplifted sediments were eroded and deposited in the basin, and their salt content was added to the salt contained in any ocean water that might have been entrapped during uplift and warping. A return of more pluvial climatic conditions or an inflow of the sea from the Atlantic brought about a period of less desiccation during which gypsum was deposited. Submergence with freer access to the Atlantic continued into Bertie time, during which, according to Miss O'Connell, rivers flowing from the north over flat-lying land formed deltas in which the remains of *Eurypterida* were deposited along with normal marine forms. An actual shrinkage of the basin area took place during the deposition of the upper Bass island, and the Bertie-Akron sediments, but contact with the ocean continued and the faunas consequently remained generally of marine character. The sediments, however, were principally derived from the surrounding emergent formations, as is shown by their being largely magnesian calcilutities. Under these restricted conditions of sedimentation, shale deposits varied greatly in character and thickness from place to place and the dolomitic deposits varied similarly, as illustrated by the thin deposits in western New York and the thick deposits in Ohio and Michigan. Minor erosion intervals occurred marked by slight disconformities as that seen in the Raisin River dolomite on East Sister island. Sand, probably eroded from the exposed St. Peter sandstone to the west, driven by the wind over barren deserts, finally formed arenaceous streaks in the upper dolomites prophetic of the close of Silurian time.

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[1] U. S. Nat. Mus., Bull. 92, pl. 3.

The end of Silurian sedimentation came in the Great Lakes region by a continued emergence of the land until all was above sea-level and the whole area was dry. Subaerial deposition of sand, rock flour, etc., went on, but this sedimentation is really epi-Silurian or transitional to the Devonian and as such sediments were largely modified by the encroaching Devonian seas, they are not described here.

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[1] Bull. Geol. Soc., Am., vol. XX, 1910, pp. 427-606.

CHAPTER VI.

ECONOMIC GEOLOGY.

INTRODUCTION.

The economic products from the Silurian rocks of Ontario may b divided into two groups: the first including those products derived directl by quarrying or mining the rocks outcropping at the surface, such a building stone, road metal, gypsum, rock for flux, and cement, lime, brick, an tile manufacture; and the second those that have to be obtained by drilling such as salt, petroleum, and natural gas. One small zinc prospect, though not of economic importance, will be described under the first division.[1]

Although the formations vary much from place to place, it has bee found quite possible to state in general terms for what purposes the roc of a formation can or can not be used. With products such as road meta and crushed stone for concrete and building stone, location is of grea importance, and it is hoped that by the use of Maps 1714 and 1715 th best outcrops may be chosen for economic development.

The raw material contained in the Silurian formations, consists magnesian limestone and dolomite of varying degrees of purity, sandston of different colour and character, waterlime, shale, gypsum, rock sal petroleum, and natural gas. Sphalerite, or zinc blende, galena, celestit and some other minerals are scattered through the dolomites in smal unimportant quantities.

For detailed descriptions of the various industries and deposits, ref to the reports mentioned in the Bibliography on: building and ornament stone by Parks; road metal by Reinecke; gypsum and salt by Cole; natu gas and petroleum by Clapp, Malcolm, and Knight.

BUILDING STONE.

MEDINA SANDSTONE.

An excellent quality of sandstone for building purposes has be obtained for many years from the Whirlpool member of the Medin Cataract formation. This stone varies locally in colour from white grey, to mottled and chocolate brown, and is best known as Credit Vall sandstone, because of the extensive quarrying carried on in the valley Credit river. The buildings of the Legislative Assembly, Toronto, built of Credit Valley brown sandstone.

The Whirlpool sandstone outcrops along the Niagara escarpme between Niagara river and a point about 8 miles south of Collingwood The outcrops occur along the lower boundary of the Medina-Catar formation, of which the Whirlpool sandstone is the lowest member in th region. The following general description is taken from Parks.[2] "Th sandstone band of the Medina formation has an average thickness about 12 feet only . . . . . most of the quarries exhibit irregula bedding, with lenses of one variety cutting diagonally across others. Thi irregularity has proved the greatest hindrance to the profitable extractio of the stone. Most of the beds are fine-grained and present roughly th types: first, a brown to chocolate-coloured variety, quarried chiefly at the Forks of the Credit; second, a white or grey variety obtained at Orangeville and from Milton northward to the Forks of the Credit; also at Hamilton; and third, a mottled variety in which blebs and bands of white occur on the brown base. This latter kind is obtained more particularly from Merriton to Grimsby. The formation occurs along the face of the Niagara cuesta from near Merriton to Hamilton. Between Hamilton and Milton the cuesta is much broken up and the exposures are few, but from the latter place northward to Cataract, outcrops are numerous. Above Cataract, the stone is hidden very largely, but an important outcrop is known east of Orangeville and again near Shelburne. At no place is the exposure wide, as it appears only along the face of the 'mountain' and has scarcely any lateral extent. The widest and most accessible places occur where the sandstone forms the top of a shoulder, on the mountain side. Much of the quarrying has been done by removing a heavy overburden or by actually mining into the side of the hill. Unfortunately, those places where the stone is most easily obtained yield a poorer produce than where it is less accessible."

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[1] This account of various raw materials used for economic purposes is supplementary to the information cont in the descriptions of the various geological formations and should be read with constant reference to the geol maps and sections.

[2] "Building and ornamental stones of Canada," vol. I, Dept. of Mines, Mines Branch, 1912, p. 139.

The more important areas for building stone are in the Credit Valley and to a lesser extent near Orangeville. Elsewhere, as in the Niagara and Milton areas, the stone is mostly used for rubble and rough coursing.

Dolomite and Magnesian Limestone. The Manitoulin dolomite is generally thin-bedded and argillaceous or clayey, and is consequently little used for other than rough coursing stone or rubble. In northeastern Owen Sound, about 25 feet of the Manitoulin beds are quarried for coursing stone; and a small amount of coursing stone has also been taken from small quarries (on lots 24 and 25, concession XI, Nottawasaga township, Simcoe county) about 8 miles south of Collingwood. In the vicinity of Manitowaning, Manitoulin island, the upper part of the Manitoulin dolomite is crystalline and probably could be worked locally for building stone. Much of the rock is thin-bedded, but at some localities it is very massive due to the presence of coral and bryozoan reefs; both of the extremes should be avoided in selecting a quarry site.

The Lockport (Niagara) dolomite, with its more or less local subdivisions, is generally suitable for building stone, and is accessible almost everywhere along the Niagara escarpment, and over large areas of Bruce peninsula and Manitoulin island. The DeCew waterlime is highly argillaceous and is consequently weak and unsuitable for building stone. The Gasport limestone of western New York is represented on the Canadian side by dolomitic limestone, highly crystalline and crinoidal in character. The Gasport loses its identity west and north of Dundas. The colour is generally dark blue, light blue, or grey, but some local areas are brown or pink. It is principally this stone which is quarried at St. Davids and Thorold where considerable amounts of dimension stone are produced.

The greater part of the Lockport formation below the Eramosa beds is grey or blue-grey on fresh fracture, weathering white, light [illegible] or creamy. Some of the lower beds are light yellowish brown on fresh fracture. In a formation of such thickness much variation is to be expected. Pore spaces are numerous and large in some horizons and particularly in those that are fossilferous, such as the "Pentamerus" beds occurring at the base of the formation in the Owen Sound district and northward.

Iron pyrites is common in the Pentamerus beds in some places and occu also at other horizons. Good stone, however, is present in large amount at most localities.

Extensive quarrying was formerly carried on near Beamsville in th lower part of the Lockport formation. At Owen Sound, beds about 2 feet above the base are quarried. At Shelburne, beds high up in th Lockport, just below the Eramosa division, are quarried. An examp of this fine stone is to be seen in the Shelburne post-office (Plate XXXIV

The upper beds of the Lockport (probably a little lower than th Eramosa beds which have not been found on Manitoulin island), we quarried extensively by the Lake Superior Corporation at Quarry poin about 7 miles south of Meldrum bay, Manitoulin island, for the stone wo of the Sault Ste. Marie canal, on the Canadian side. The stone weathe grey, and has apparently been very satisfactory for the purpose for whi it was used. Huge piles of waste at the quarry, however, show that mu sorting of material was done. Many localities along the northern sho of the western end of Manitoulin island and Cockburn island afford exc lent opportunity of obtaining Lockport dolomite of good quality at near the water's edge.

The Eramosa dolomite is characteristically thin and even-bedde At some localities these beds are almost as cleavable as slate, and towa the top the partings are commonly bituminous. The colour is genera dark grey, banding of different shades being common. Near the city Guelph, brown shades predominate.

The Eramosa beds outcrop below the base of the Guelph formation many localities, but they and the Guelph are not known on Manitou island.

At a quarry west of Wiarton (lots 7 and 8, concession XIV, Ama township, Bruce county) the upper Eramosa beds are worked. The th even-bedding, characteristic of this division of the Niagara, is here of gr value in the production of stone of uniform thickness such as is requi for monument bases and sills. The Eramosa beds are also quarried Hamilton and Dundas, but at present the output is for road metal, concr etc.

The Guelph dolomite varies much in character according to loca and horizon. The lower few feet are rather thick-bedded, but partak the bituminous nature of the underlying Eramosa beds. The colou consequently brown and a strong oily smell is common. These beds not used for building stone. Beds higher up are commonly fine-gra and dense, the bedding being thin and the colour light brown or g The beds near the top of the formation and those which appear to belon the middle third are commonly light grey or cream-coloured, weath sandy. Pore spaces are numerous and are of various sizes, being par larly large in the more fossiliferous beds. The bedding in the upper div is generally thick to massive.

The lower, fine-grained Guelph beds are not used for building st although quarried at Fergus for crushed stone and lime. Beds a higher were formerly used at Fergus, Elora, and Guelph for local const tion, as were the upper fossiliferous beds at Hespeler and Galt. The from the higher beds is porous but cuts easily and gives a very plea effect in the walls and trimmings of the buildings in which it has been u Its wearing qualities are good. Large quantities of Guelph dolomite available in the vicinity of the towns cited above, as well as at many other places within the Guelph area, especially on Bruce peninsula. As there is a considerable demand for crushed stone in the more thickly settled parts of the country, waste material from building stone quarries can be readily disposed of.

The Cayugan formations contain no beds that are very suitable for building. The Salina formation consists of shales and thin, impure dolomites in the lower part and brittle dolomites and waterlimes in the upper or Bertie division. The overlying Akron dolomite is thin-bedded and jointed. The Bass Island (Lower Monroe) formations of the Lake Huron and Detroit River regions are similar in character to the Bertie and Akron divisions with which they are correlated in this report.

ROAD METAL AND CRUSHED STONE.

The finer-grained, harder, Silurian dolomites are well suited for the construction of macadam roads subjected to medium traffic. The more porous, crystalline beds should be carefully avoided as the rock is too soft and crumbly to be useful for road metal.

The Manitoulin dolomite (Cataract) is quarried for coursing stone and road metal at Owen Sound and this material would doubtless also be useful for crushed stone for concrete work. L. Reinecke found this stone to be inferior in toughness, and to be suitable only for roads subjected to very light traffic. On the eastern part of Manitoulin island, the Manitoulin dolomite is very similar to the Lockport in character and would doubtless give good results for crushed stone and road metal.

The Clinton limestone thins out in Ontario and generally outcrops in the face of the Niagara escarpment in such a way as to be inaccessible for quarrying. The upper beds are tough and hard to work, particularly in the vicinity of Hamilton and Ancaster where they are known as the "Niagara Head" beds. The lower Clinton beds occur at the base of the Loc [illegible] far north as Kelso. Except for their inaccessibility, the Clinton be [illegible] probably be useful for crushed stone and road metal.

The Lockport dolomite is extensively used for crushed st [illegible] concrete and road metal. The largest quarry in this formation [illegible] operated by the Canada Crushed Stone Corporation, Limited, at Dun [illegible] The lower 32 feet of strata here are the Eramosa beds and the upper 25 are Guelph. This stone has been favourably reported on for road metal by Reinecke[1]. According to his report it is suitable for roads subjected to light traffic and is one of the very best of the limestone-dolomite group in the country. Other quarries are operated in the Lockport at St. Davids, Thorold, Hamilton, Ancaster, Waterdown, Orangeville, and elsewhere. According to Reinecke, tests made on the stone at Ancaster show it to be very similar to that at Dundas. Stone of the general characters of that already tested could be obtained at many places along the Niagara escarpment and at other localities over the extent of the Lockport outcrops.

The Eramosa beds at the top of the Lockport dolomite are cleavable, siliceous and bituminous in part, and as shown above are found suitable for road metal at Ancaster, Dundas, and elsewhere. Outcrops of these beds are to be found east of Guelph, in the quarries at Ancaster and Dundas, at the quarries for dimension stone west of Wiarton, at Halfway rock, on

[1] [illegible]

the north shore of Bruce peninsula, and on Flowerpot and other islands i Georgian bay. These beds are generally capped by tough Guelph strat with which they could be quarried to good advantage, as is done at Ancast and Dundas.

The Guelph dolomite varies much in character, but where fine-graine is very resistant and furnishes splendid material for crushed stone fo concrete, artificial stone, and road metal. The quarries operated at Ga and Fergus furnish good stone for such purposes. Reinecke reports tha the stone from the Gow quarry, Fergus, is suitable for light traffic only It has, however, worn well on local roads. The upper 2 or 3 feet at Ancast and the upper 25 feet of strata quarried at Dundas are Guelph. A larg quarry is operated by the Canadian Pacific railway for ballast, about o mile south-west of Shaw station, and quarries are operated at Rhymal an elsewhere. Many opportunities occur for opening quarries in the Guelp rock over the extent of its outcrops, but where road metal is required, on the hardest and densest stone should be selected; a selection can general be made by examining the surface exposures.

The Bertie-Akron dolomites furnish good road metal in the vicinit of Byng near Dunnville. Similar rock occurs west of Cayuga and in th bend of the Saugeen river about $2\frac{1}{2}$ miles north of Walkerton (see pa 89). The outcrops of rock at Innerkip and on the islands west of Pel island, belonging to the Bass Island series, would be serviceable for crushe stone and road metal.

CEMENT.

Magnesian limestones carrying considerable quantities of argillaceous (clayey) matter, and known as waterlimes, were formerly burned in kilns to a natural rock cement which possessed the characters of a low grad Portland cement. With the standardizing and increased manufacture high grade cement, the natural rock cement industry has died out.

DECEW WATERLIME BEDS.

At one time considerable amounts of the DeCew beds were mined at St. Davids, Thorold, and DeCew falls, for the manufacture of natural rock cement. Quarries were also worked in these beds at Mount Albion and probably elsewhere. Six feet of cement rock was worked at S Davids, and 8 feet at Thorold and DeCew falls. At St. Davids and Thorold the rock was mined on the room and pillar system, the entrances being levels run from nearby quarries. The cement manufactured Thorold was used in the building of the Welland canal and Victoria brid For analysis of the DeCew beds see page 112. The DeCew beds available for mining at various places along the Niagara escarpme between Hamilton and Niagara river.

BERTIE WATERLIME.

About 6 feet of Bertie waterlime was formerly quarried at North Buffalo and burnt to natural rock cement. Beds of similar charac occur at quarries north of Ridgeway (lot 1, concession X, Bertie township and in the quarries at and near Byng across the Grand river from Dunnville. Should a demand arise for such rock, it may be obtained at places mentioned and also in the vicinity west and south of Bridgebur Ontario.

PORTLAND CEMENT.

No limestones low enough in magnesia for the manufacture of Portland cement are found in the Silurian system of southwestern Ontario. Such limestones should be sought in the areas underlain by Ordovician (e.g. Trenton) and Devonian (e.g. Onondaga) formations.

DOLOMITE FOR FLUX.

Dolomite or high magnesian limestone is required in the sulphite process of paper-manufacture from pulpwood and also for flux in the basic open-hearth process of steel manufacture. Because dolomite may be obtained more cheaply for some blast furnaces, for example at Hamilton, it is used for flux instead of limestone, which is otherwise preferred. Dolomites from Rhymal and Dundas are used in the Hamilton blast furnaces. About 30 per cent of the total production, including the entire upper bed of the rock quarried at Dundas by the Canada Crushed Stone Company, is sold for flux for blast furnaces. From the analyses (pages 110 to 116), the characters of the Silurian dolomites may be studied. The distribution of the various formations is given in the chapter on stratigraphy.

MANUFACTURE OF CHEMICALS.

High grade limestone such as is required for chemical manufacture is not found in the Silurian formations. This is to be found in the Onondaga and Anderdon limestones at Amherstburg and Beachville[1].

Dolomite is suitable for the manufacture of carbon dioxide, and the purer forms such as are found in the Niagara and Guelph formations are easily available for such purposes.

DOLOMITE FOR LIME MANUFACTURE.

Magnesian limestone and dolomite burn to quicklime which makes strong mortar, although it is somewhat slow in setting. For the manufacture of hydrated lime, the presence of considerable quantities of magnesium carbonate in the rock is essential.

Formerly all the Silurian dolomites were burnt to some extent for quicklime. The lime-kilns were largely operated by farmers to supply the local demand, wood being used as fuel. The remains of old kilns near rock outcrops, in nearly all parts of the country, testify to the source of the lime used in local building enterprises.

The Manitoulin dolomite was burnt for lime on many parts of Manitoulin island, and especially near Manitowaning and Gore Bay. The Lockport dolomite was formerly burnt at many localities along the Niagara escarpment, and is still burnt at Ancaster, Kelso, Limehouse, Rockwood, Owen Sound, and elsewhere.

Guelph dolomite is burnt to quicklime at Puslinch, Hespeler, Galt, Elora, Fergus, and in the vicinity of Guelph, where it is also manufactured into hydrated lime by the Standard White Lime Company.

The Bertie-Akron dolomite was formerly burnt to quicklime at Springvale, Innerkip, 2½ miles north of Walkerton along the Saugeen river, and 2 miles south of Pinkerton.

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[1] [illegible] urv., Can., Mem. 34, 1915, pp. 271, 274, 279.

Great quantities of raw material are available for the manufacture of hydrated and ordinary lime. It is obvious that in choosing a quarry site, cherty dolomite and dolomite full of clayey impurities should be avoided. For analyses of the various rocks see pages 110 to 116.

SHALE FOR BRICK AND TILE MANUFACTURE.

The Cabot Head shale as known on the mainland of Ontario is too sandy or else contains too many calcareous beds to be useful in the manufacture of brick or tile. A considerable thickness of nearly uniform, red, plastic shale is found, however, in the Cabot Head shale of Manitoulin island. A sample of this shale collected by the author on the road allowance on lot 16, concession IX, Billings township, was submitted to J. Keele, chief of the Ceramic division, Mines Branch, Department of Mines, who reported on it as follows:

"This shale is very plastic, smooth, and stiff, when tempered with water. Owing to its stiffness it is hard to work, and would be improved in this respect by the addition of sand.

The material dries without cracking, with shrinkages within working limits, and burns to a hard, dense, red body at low temperatures.

This clay appears to be suitable for the manufacture of building brick, hollow ware blocks, and field drain tile. It may be possible to use it for roofing tile also."

The shale from which the sample was taken occurred in a 50-foot section exposed along the road for about one-eighth of a mile. It is situated about 2½ miles from West bay, Indian village. A smaller exposure occurs on lot 28, concession IX, Allan township, about 3 miles southeast of the town of Gore Bay. The clay is exposed in the road on both sides of a small hill, which is capped with an impure dolomite. Large quantities of clay could doubtless be obtained below the surface soil on the flanks of the hill.

Other less favourably located outcrops of this shale occur on Manitoulin island, one of the best being on lot 27 on the road between concessions d V, Bidwell township, and 1¼ miles west of lake Manitou.

ZINC BLENDE.

Small particles of galena and sphalerite, or zinc blende, are widely scattered through the Niagara and Guelph dolomites. Particles of galena may be found in the Lockport dolomite at the top of the falls at Grimsby at Rockwood, and east of Guelph. Zinc blende may be seen at Rockwood and elsewhere.

The only notable amount of zinc blende reported, however, was discovered by Dr. Wolverton of London, on lot 30, concession II, Albermarle East township, Bruce peninsula, about 4 miles northwest of Wiarton. Under the direction of Mr. G. B. Bourne considerable prospecting has been done since , an excavation having been made measuring approximately 30 feet in length, 10 feet wide, and 25 to 30 feet in greatest depth (not 100 feet by 30 feet by 30 feet, as reported in the Summary Report, 1912, page 281). The rock is massive, very scraggy, and full of pore spaces and cavities, and when fresh is a light blue colour. The large amount of pore spaces and cavities is principally due to the solution of fossils which are large and numerous, some of the cephalopods being over 1 foot long and 6 inches in diameter. The zinc blende occupies these cavities, the mineral in some cases partly replacing fossils. The action of surface waters has in some cases caused a concentration of pieces of zinc blende at the bottom of small pockets, into which the blende has fallen on being released from the rock by solution of the dolomite to which it was attached. About 110 pounds of loose blende is said to have been obtained in such a pocket, where it was mixed with soil and pieces of rock. The ore continues down to a depth of 20 feet, below which no ore has been found.

A shipment of several hundred pounds of this ore was made previous to 1912, the lot being said to assay 69·76 per cent zinc. When last visited (September 1916) about two cords of hand-picked ore was piled up alongside the prospect.

The zinc blende occurs in dolomite of lower Guelph age, closely related in fauna to the Racine beds of Wisconsin. Not far below the zinc deposits is the top of the Eramosa, arenaceous dolomite forming the upper division of the Lockport formation. These beds, because of their fine-grained, impervious nature have doubtless prevented downward movement of the surface waters, which on this account moved entirely in a lateral direction, dissolving such minerals as zinc blende under favourable conditions for solution and precipitating them where numerous pore spaces and cavities existed owing to the solution of fossils. The accumulation in local pockets is doubtless very recent, and due to surface solution.

GYPSUM.

Extensive gypsum deposits occur in the Salina[1] formation of western New York and of the adjoining Niagara peninsula of Ontario as far west as the vicinity of Paris. The gypsum occurs near the top of the Camillus shale and just below the Bertie waterlime (see the description of the core drill record at Buffalo). Some gypsum occurs at the top of the shale throughout Ontario peninsula, as we may judge from evidence of well borings. In the west and north, however, gypsum occurs in small amount and salt occurs in large quantities lower down in the Salina. For further discussion of the Salina formation and the origin of the gypsum deposits, see Chapter V, page 84.

The workable deposits of gypsum, as at present known, occur along Grand river between the old gypsum mines, 4 miles southeast of Cayuga, and old workings about 1 mile northeast of Paris. Grand River practically follows the outcrop of the gypsum, which being quite soluble has been easily eroded away. Cole[2] has mapped the workable gypsum deposits in such a way as to separate the above region into two areas, a western area included within a radius of 2 miles of Paris and not definitely determined towards Brantford; and an eastern area of oblong shape extending from a point about 4 miles east of Brantford to the bend of Grand river 4 miles west of Dunnville, the greatest width being about 6 miles in the vicinity of York. These areas contain the workable deposits at present known, the only actual mining being carried on in the vicinity of Caledonia and York. Well records, however, indicate gypsum throughout Niagara peninsula, although the exact thickness is not indicated in most logs of wells kept by the gas companies. In New York state, exploration is being done at more than 100 feet in depth and it is the cost of production compared with the market price which will determine the limit in depth at which the Ontario gypsum may be worked. As the average southerly dip per mile of the geological formation is about 30 feet, it will be seen that $3\frac{1}{3}$ miles south of the outcrop, a bed of gypsum will be approximately 100 feet lower than at the outcrop. Differences in the elevation of the surface of the land must of course, be taken into account in estimating the depth of the gypsum below the surface. The gypsum is without doubt lenticular, but the horizon is extensive and there seems no reason to suppose that deposits as good as those already known may not yet be discovered in Niagara peninsula, at, however, greater depths than those now being worked. Under present conditions, the cost of working such deposits would doubtless be prohibitive.

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[1] Formerly known as the Onondaga formation: Onondaga is now properly used for a Devonian formation [illegible]

[2] [illegible] in Canada," Dept. of Mines, Mines Branch, 1913, p. 76

For detailed discussion of the gypsum industry of Grand valley, see "Gypsum in Canada."[1]

On January 1, 1917, the two companies formerly operating in Grand River valley, viz., the Alabastine Company, Limited, of Paris, and the Crown Gypsum Company, of Lythmore, amalgamated under the name of the Ontario Gypsum Company, Limited. The Alabastine Company manufactured wall tints, known as alabastine, and wall plaster, as well as ground gypsum for retarder in the manufacture of portland cement and for fertilizer or land plaster. The Crown Gypsum Company manufactured wall plaster. The operations of the two companies are now carried on by the Ontario Gypsum Company.

The principal mine formerly worked by the Alabastine Company is on lots 10 and 11, concession 1, west of the Hamilton road, Seneca township, Haldimand county. About 15 acres have been mined, operations being carried on in part on three different levels. The room and pillar method of mining is followed, the rooms on the second level being 20 feet square and the pillars 12 feet; the rooms on the third level are 18 feet and the pillars 14 feet. Underground haulage is done by means of horses and the gypsum is finally raised to the surface along an incline by steam power. Self-dumping cars carrying the gypsum in steel half cylinders are used. Little water is encountered, the mine being so dry and comfortable that the visiting members of the Twelfth International Geological Congress were served dinner by the Alabastine Company in August, 1913, in the main station of the mine on the second level.

The product of this mine is green gypsum which is used in the manufacture of land plaster and as a regulator for the setting of portland cement. Large reserves are held north of the present workings.[2]

The Carson mine "located about three miles south of Caledonia village in Oneida township" supplied the Alabastine Company with pure white gypsum for its finer products. The bed of gypsum worked[3] is about 4 feet thick, and mining is carried on as at Caledonia. "Overlying the bed of white gypsum are layers of dolomitic shales and limestones, in all from 4 to 6 feet in thickness, covered by 40 to 50 feet of post-Glacial drift. The roof here is not in as safe a condition as at Caledonia, where the grey beds are from 9 to 12 feet in thickness, overlying which are 40 to 50 feet of dolomitic limestone and shales covered by the post-Glacial drift."

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[1] Ibid, pages 57 to 77.

[2] Ont. Bureau of Mines, 1915, vol. XXIV, pt. 1, p. 150

[3] Ont. Bureau of Mines, 1915, vol. XXIV, pt. 1, p. 150.

The mine formerly operated by the Crown Gypsum Company is situated near the village of York on the south side of Grand river, on lots 58 and 59, Oneida township, Haldimand county. This is known as the Martindale mine.

The following is taken from Cole's description, page 67.

"The property on which this Company's working mine is situated is one of the first places in this district from which gypsum was mined. With the exception of about twelve years, this gypsum bed has been operated continuously since about 1866.

The beds are covered with about 70 feet of drift, shale, and limestone. The one that is being worked is reached by an incline tunnel 500 feet in length with a bearing of north 73 degrees east. This bed consists of very high grade, white gypsum suitable for the best grades of plaster of paris, and breaks clean to both floor and back so that very little waste has to be sorted out underground. Hand power is employed for drilling the waste rock in the mine. The bed has an average thickness of about 4 feet and as only the gypsum is broken, the workings are consequently very low thus making moving around underground very difficult.

The method of mining the gypsum in this mine is very similar to the room and pillar method employed in coal mines......"

For descriptions of the abandoned mines and prospects see Cole's report.

The output of gypsum for Ontario reached a maximum in 1914[1], the production being: gypsum mined, 89,157 tons; gypsum shipped, crushed, or ground, 43,183 tons; ground and calcined gypsum used in gypsum products, 33,705 tons; the manufactured products being valued at $162,375 and the total production $221,175.

The total output in 1917, crushed, ground, and calcined,[2] was 48,656 tons valued at $128,828. This is a falling off of 44,744 tons since the maximum production of 1914, which was 93,400 tons of gypsum and gypsum products.

SALT.

The total Canadian production of salt is obtained from the Camillus shale of the Salina formation of the Ontario peninsula. As shown on Cole's map,[3] the productive salt deposits are approximately included in the area lying between lake Huron, St. Clair river, and lake St. Clair on the west, and a line [illegible] from the shore of lake Huron at Inverhuron south through Brussels half-way between Seaforth and Dublin, to the east of London and to lake Erie shore half-way between Dutton and Port Stanley. The southern boundary extends from near the Elgin-Kent boundary on lake Erie shore through Thamesville, and to the shore of lake St. Clair a few miles north of the mouth of Thames river. A small area in the vicinity of Windsor is also salt-producing. The salt occurs in several beds which are more or less lenticular, as is illustrated by the occurrence of 125 feet of salt (with some shale beds) in a well bored on the south side of Thames river about 2 miles west of Prairie siding, although no salt was reported in the wells drilled all around this locality. Another similar occurrence is that of 400 feet of salt penetrated in a well in the Wheatley oil field. The most extensive gypsum deposits do not occur in the salt area, but considerable gypsum is found in the Camillus shale overlying the salt. Some gypsum is interbedded with the salt at Goderich and gypsum occurs below the salt at Courtright. However, owing to the small amount of gypsum present and to its lower solubility than salt, little trouble is experienced in the manufacture of salt from Ontario brines.

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[1] Ont. Bureau of Mines, 1915, p. 42.

[2] Ont. Bureau of Mines, Bull. 33, 1917, p. 3.

[3] "Salt deposits of Canada and the salt industry," Dept. of Mines, Mines Branch, 1915, opposite p. 20

Several beds of salt may be penetrated by a well; for example six occur at Goderich, the total thickness of salt being 126 feet. At Windsor, four beds are reported with a total thickness of 427 feet.

Salt is obtained by evaporating the brine pumped up from the wells. The water forming this brine is allowed to flow into the wells, usually from a water-bearing stratum high above the salt. Evaporation is accomplished by steam heat or by a vacuum process.

Besides the general production of table, dairy, and coarse salt for meat packing, etc., caustic soda and bleaching powder are manufactured by the Canadian Salt Company at Sandwich.

Salt was first discovered by Mr. Platt at Goderich in 1866, while drilling for oil. At present, salt is manufactured at Goderich, Kincardine, Wingham, Clinton, Exeter, Parkhill, Elarton, Sarnia, Courtright, Windsor, and Sandwich. The total production[1] for 1917 was 138,528 tons, valued at $1,095,866. This is the maximum production to date. In 1916, 305,900 pounds, valued at $2,223, were exported and 151,208 tons, valued at $694,835, were imported, including 109,493 tons, valued at $523,725, imported from Great Britain for the use of coast fisheries.[2]

Analyses of Brine from Rock Salt, Southwestern Ontario[3].

Hypothetical combination: 1,000 parts by weight contain:

	I	II	III	IV	V	VI	VII	VIII
NaCl	244·860	253·105	266·415	258·770	263·921	260·812	245·111	256·891
$CaCl_2$	1·265	1·066	1·895	1·484	0·477	0·111	4·964	1·007
$MgCl_2$	0·966	0·534	1·884	1·017	2·040	0·297	0·503	0·467
$CaSO_4$	[illegible]·728	4·037	2·757	3·730	3·939	4·476	2·405	3·971

I. Western Canada Flour Mill's well, Goderich, Ont.
II. American Chemical Co.'s well, Goderich, Ont.
III. Stapleton Salt Works, Clinton, Ont.
IV. Ontario Peoples Salt and Soda Co., Kincardine. Ont.
V. Sparling Co., Wingham, Ont.
VI. Western Salt Co., Mooretown, Ont.
VII. Dominion Salt Co., Sarnia, old well.
VIII. Dominion Salt Co., Sarnia, new well.

Analyses of Brine from the Platt Well at Goderich[4].

—	Parts per 1,000.	In 100 parts of solid residue.
NaCl	259·000	99·018
$CaCl_2$	0·432	0·165
$MgCl_2$	0·254	0·097
$CaSO_4$	1·882	0·720
	261·568	100·000

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[1] Ont. Bureau of Mines, Bull 33, 1917, p. 3.
[2] Mines Branch, Dept. of Mines, Sum. Rept., 1916, p. 174.
[3] "Salt deposits of Canada," table III, p. 48.
[4] Geol. Surv., Can., 1866, p 269.

As no analyses of the brines from the Windsor wells are at hand the following analysis is given to represent this region.

Artificial Brine Direct from the Well of the Delray Salt Company, Delray, Michigan, near Detroit[1].

KCl	trace
NaCl	290·6
$CaCl_2$	trace
MgCl	3·6
$CaSO_4$	3·1
$MgBr_2$	trace

Analyses of Brines from New York State, for Comparison[2].

	I	II
$MgCl_2$	0·155	0·049
$CaCl_2$	0·129	0·134
$CaSO_4$	0·599	0·349
NaCl	16·921	23·295

I. From the Onondaga natural brine.
II. From artificial brine from the solution of the rock salt.

Analyses of Rock Salt from Attrill Well, Goderich[3].

	I	II
NaCl	99·687	91·24
$CaCl_2$	0·032	0·57
$MgCl_2$	0·095	0·05
$CaSO_4$	0·090	2·81
Insoluble	0·017	5·33
Moisture	0·079	
	100·000	100·000

I. From the white translucent portion of the second bed in the Attrill well core.
II. From the less pure salt from the same bed.

The following comparison is by Hunt.[4]

	Impurities.
	Per cent.
Cheshire salt	2·67
Cordova, Spain, salt	1·45
Turks Island salt	2·34
Saginaw salt	2·00
Syracuse solar salt	1·15
Syracuse boiled salt	1·50
Goderich coarse salt (analysis made in 1871)	1·09
Goderich medium salt	1·28
Goderich fine salt	1·62

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[1] Cook, C. W., Mich. Geol. and Biol. Surv., Pub. No. 15, geol. ser. 12, p. 89.
[2] Newlands, D. H., N.Y. State Mus., Bull. 174, p. 68.
[3] Geol. Surv., Can., 1866, p. 269
[4] Geol. Surv., Can., vol. V, pt. II, p. 164 s.

For further comparison, the following analyses of rock salt are adde

Analyses of Rock Salt from New York State.

	I	II
Moisture	trace.	trace
Insoluble	0·7430	0·0581
$CaSO_4$	0·4838	0·0793
$CaCl_2$	0·0180	0·0358
$MgCl_2$	0·0546	0·0888
NaCl	98·7000	99·7410

I. An average sample of salt mined in New York state.
II. "Perfectly white salt."

The superior quality of the Ontario salt is clearly illustrated comparing the above analyses.

PETROLEUM.

Of the petroleum obtained from southwestern Ontario, only a sm part comes from Silurian formations, the most of it being found in the Onondaga (Corniferous) limestone of the Devonian system. Some oi however, is obtained from the Whirlpool sandstone in Onondaga township Brant county, and from the top of the Guelph and the lower Salina of the Tilbury field and the Guelph of the Wheatley field.

The oil production from the Whirlpool sandstone is obtained[2] from Onondaga township, Brant county, about 7 miles east of Brantford along Fairchild creek, and from an area approximately 1½ miles long by 1 mile wide. The Whirlpool sandstone is here 20 feet thick and lies 500 feet below the surface. This field was opened in 1910, reached its maximum production of 13,501 barrels in 1911, and produced 1,617 barrels in 1916.

As interpreted from drill records, the upper Guelph and lowest Salina strata yield oil in the Tilbury field, which is situated in the eastern part of East Tilbury and the western part of Raleigh townships, Kent county. Including the gas field which extends to lake Erie and includes the eastern point of Romney township, the field is 9 miles in length from north to south and 8 miles in greatest width which is along the shore of lake Erie. In the vicinity of Stewart, East Tilbury, gas is reported from a depth of 1,363 feet and oil from 1,393, 1,418, and 1,430 feet.

Oil is also obtained from the Guelph formation in the Wheatley fi at a depth of 1,290 and 1,300 feet. This field includes a small area east of Wheatley in the southwestern part of Romney township.

The production of oil for Tilbury and Romney, which was 106,99 barrels in 1906, reached a maximum of 411,588 barrels in 1907 and the rapidly fell off, being 16,297 barrels for 1916 (as reported for Tilbury presumably including the Wheatley field)[3] which was a gain of 3,55 barrels over 1915, the lowest output since the opening of the field.

Oil in Ontario is generally found to occur at the top of domes an anticlines, where it is driven by the greater specific gravity of salt w In the case of formations that contain no water this rule does not

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[1] Merrill, Frederick G. H., Bull. N.Y. State Mus., No. 11, 1893, p. 37
[2] Geol. Surv., Can., Mem. 81, 1915, p. 61.
[3] Ont. Bureau of Mines, vol. XXVI, 1917, p. 52.

but the Silurian formations containing oil generally contain salt water also. The present tendency is to explore the Guelph and Salina formations, where not already tested, below the domes and anticlines discovered in the development of the shallower oil fields (Onondaga or "Corniferous") (see structure, pages 11 to 14).

GAS.

Most of the gas found in Ontario is from formations of Silurian age. The Medina-Cataract sandstones and shales, the Clinton limestone, the Guelph dolomite, and the Salina shale all bear locally important quantities of gas.

The Medina sandstones are generally gas-bearing. Quoting Malcolm[1] "The greater proportion of the gas of the Selkirk, Port Dover, and Delhi fields is derived from the red Medina sandstone (Grimsby member), although small quantities are found also in the white Medina sandstone (Whirlpool member), and in the Clinton formation. The White Medina sandstone is the productive horizon for the gas of the Bertie-Humberstone, Wainfleet, Ottercliffe, Bayham, Onondaga, and Brantford fields. . . . Some of these fields derive a portion of their gas also from the red Medina sandstone and the Clinton formation." For the depths at which the top of the Medina is reached in the various fields, see Malcolm, page 29, and cross-sections and logs in this report.

The Clinton formation, according to Malcolm, supplies gas "in the Onondaga, Caledonia, and Cayuga fields, and is the most productive horizon at Port Colborne, west of the canal." For depths, see Malcolm, page [illegible], and logs given in this report.

Malcolm states "the Guelph is the gas-bearing formation of Gosfield, Mersea, and Wheatley. . . ." At Gosfield, the top of the formation is about 1,000 feet below the surface and at Mersea about 1,100 feet. For further information as to depths, see Malcolm, page 34.

"The Salina (Onondaga) is the gas-bearing formation of the Kent gas field. . ." (Malcolm, page 36, see page 37 for depths of top of formation.)

For the chemical composition of the natural gases of Ontario, see 23rd Annual Report of the Ontario Bureau of Mines, 1914. pp. 247-259.

It is now well recognized that the occurrence of natural gas and oil in the Silurian formations of Ontario is principally dependent upon rock porosity and structure such as anticlines, domes, monoclines, etc., and consequently developing companies are paying more and more attention to lenses of porous strata and to structure as worked out from well logs. The keeping of careful logs of the formations penetrated in drilling, and the depth at which water is struck, etc., is of great importance for the future development of oil and gas in Ontario (for structure see page 11).

According to the Bureau of Mines[2] the total gas production for Ontario in 1916 was 17,953,000,000 cubic feet, valued at $2,404,499, as compared with 15,211,500,000 cubic feet in 1915. Of this amount, Welland-Haldimand produced 3,769,500,000, Kent 13,752,500,000, Elgin 351,-900,000, and Lambton 55,200,000 cubic feet. The amount for 1917[3] was 20,025,700,000 cubic feet, valued at $3,182,154.

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[1] Ibid., page 28

[2] Ont. Bureau of Mines, vol XXVI, 1917, p. 46.

[3] Ont. Bureau of Mines, Bull. 33, p. 3.

ROCK ANALYSES.

MEDINA-CATARACT FORMATION.

Manitoulin dolomite, from Mitchell's Mills, lot 8, concession XI Collingwood township, Grey county. Analyses by Mines Branch, Dep of Mines, Ottawa.

$CaCO_3$	66·00
$MgCO_3$	20·54
$FeCO_3$	1·05
Fe_2O_3	0·06
Al_2O_3	0·73
Insoluble	10·70
Total	99·08

Analyses of Manitoulin Dolomite on Manitoulin Island[1].

	I	II	III	IV
Insoluble matter	....	....	3·86	
Silica	4·64	5·68	...	7·64
Ferric oxide	1·12	0·81	0·72	0·94
Alumina	1·80	2·85	0·32	2·44
Lime	28·61	28·08	29·00	26·59
Magnesia	19·60	19·10	20·48	18·82
Carbon dioxide	43·79	43·00	45·27	41·57
Loss	....	0·16	0·22	0·25
Sulphur trioxide	....	0·30	0·12	0·31
Alkalis	....	....	0·66	
Total	99·47	99·98	100·65	98·56

I. Gore Bay, sample of 12 feet of uppermost part of face of cliff, northw Fair grounds.

II. Top of cliff across bay, east of Gore Bay.

III. Gore Bay, one-quarter mile west of northwest corner of Fair grounds, 6 feet.

IV. Porter's quarry, just east of Fair grounds, Gore bay.

V. Landing at lake Manitou.

Calcareous sandstone bed thought to represent the southern exte of the Manitoulin dolomite, as taken by the author in the Niagara gorge above Lewiston. Analysis by Mines Branch, Dept. of Mines, Ottawa.

$CaCO_3$	38·39
$MgCO_3$	22·95
$FeCO_3$	3·14
Fe_2O_3	0·07
Al_2O_3	3·42
Insoluble matter	32·38
Total	101·35

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[1] Ont. Bureau of Mines, 1904, pt. II, p. 75. The formation is identified by the writer from his knowledg localities described.

A sample taken from a 6-foot bed of ferruginous limestone in the upper part of the Cabot Head shale at Limehouse. Analysis by Mines Branch, Dept. of Mines, Ottawa.

$CaCO_3$	28·84
$MgCO_3$	21·59
$FeCO_3$	2·05
Fe_2O_3	20·72
Al_2O_3	2·48
Insoluble	22·18
Total	97·86

CLINTON FORMATION.

Clinton, basal, sandy, glauconitic layer about 2 or 3 inches thick, at Dundas. Analysis by Mines Branch, Dept. of Mines, Ottawa.

SiO_2	22·42
Al_2O_3	3·46
FeO	2·72
Fe_2O_3	2·97
CaO	19·80
MgO	13·92
H_2O	3·50
CO_2	not determined.
Total	68·79

Reynales (Wolcott) dolomite at Hamilton. Analysis by Mines Branch, Dept. of Mines, Ottawa.

$CaCO_3$	50·85
$MgCO_3$	35·28
$FeCO_3$	2·11
Fe_2O_3	0·07
Al_2O_3	0·50
Insoluble	10·90
Total	99·71

Irondequoit dolomite, at Hamilton. Analysis by Mines Branch, Dept. of Mines, Ottawa.

$CaCO_3$	53·69
$MgCO_3$	39·19
$FeCO_3$	2·38
Fe_2O_3	trace
Al_2O_3	0·39
Insoluble	4·24
Total	99·89

NIAGARA GROUP.

Analyses of Rochester Shales.[1]

	I	II
SiO_2	22·00	22·52
Al_2O_3	12·65	8·12
FeO	1·77	1·13
Fe_2O_3	0·46	1·01
CaO	20·81	21·83
MgO	7·77	10·14
H_2O	7·20	4·00
Total	72·66	68·75

I. Rochester shale, 3 feet above base at Hamilton.
II. Rochester shale, upper 4 feet, at Hamilton.

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[1] Analyses by Mines Branch, Dept. of Mines, Ottawa.

Analyses of DeCew Waterlime Beds, Lockport Dolomite.[1]

	I	II
SiO_2	21·70	11·4
Al_2O_3	5·88	5·10
FeO	0·90	0·67
Fe_2O_3	1·28	1·2
CaO	23·62	20·2
MgO	12·98	15·9
H_2O	1·00	5·60
CO_2	not determined.	
Total	67·36	63·3

I. About middle of beds at St. Davids.
II. Redhill creek, west of Mount Albion.

Analyses of DeCew Waterlime, from Thorold Quarries, Used in Piers of Victoria Bridge.[2]

	I	II
Calcium carbonate	56·28	47
Magnesium carbonate	20·07	30
Alumina and ferric oxide	2·20	2
Insoluble argillaceous residue	20·90	19
Water and loss by ignition	0·31	0
Total	99·76	99

I. John Brown's quarry.
II. Alex. Manning's quarry.

Rock at base of Lockport formation at Limehouse formerly burnt f hydraulic lime; probably DeCew waterlime[3].

Carbonate of lime			48·07
" magnesia			39·63
" iron			0·69
Sulphate of lime			0·10
Alumina		0·21	11·60
Silica, soluble		0·37	
Insoluble matter, consisting of			
Silica	7·60	11·02	
Alumina	2·07		
Ferric oxide	0·40		
Lime	0·05		
Magnesia	0·19		
Potassa	0·53		
Soda	0·18		
Total			100·09

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[1] Analyses by Mines Branch, Dept. of Mines, Ottawa.
[2] Ont. Bureau of Mines, 1904, pt. II, p. 15.
[3] Geol. Surv., Can., vol. VIII, [illegible]

Analyses of Lockport Dolomite[1]

	I	II	III
$CaCO_3$	55.30	54.28	53.48
$MgCO_3$	42.28	39.00	42.55
$FeCO_3$	0.82	1.66	0.24
Fe_2O_3	0.14	0.57	0.07
Al_2O_3	0.15	0.29	0.12
Insoluble	1.24	3.00	3.50
Total	99.93	98.80	99.96

I. 3-foot bed above 6-foot bed of Reynales (Wolcott) dolomite, at Kelso
II. Beds about 23 feet above DeCew beds, at St. Davids.
III. Government quarry at Providence Bay, Manitoulin island.

Analyses of Lockport Dolomite from Manitoulin Island[2]

	I	II
Insoluble		
Silica	1.43	1.42
Ferric oxide	0.71	0.99
Alumina	0.59	
Lime	30.05	30.06
Magnesia	21.19[3]	20.46
Carbon dioxide	46.00	47.00
Total	99.97	99.93

I. Top of hill at Meldrum Bay village.
II. Fossil hill, near Manitowaning

Analyses of Lockport dolomite from Ryan and Haney's Quarry, near Meldrum Bay, Manitoulin Island.[1]

	I	II
[illegible]	0.40	0.56
Ferric oxide	0.50	0.41
Alumina	trace	0.20
Lime	30.84	30.50
Magnesia	21.11	21.55
Carbon dioxide	47.40	47.40
[illegible]	0.18	
[illegible] oxide	0.09	0.23
[illegible]	0.15	0.05
Total	100.67	100.90

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[1] Analyses by Mines Branch, Dept. of Mines, Ottawa

[2] [illegible]

[3] [illegible] 11.39 which is evidently incorrect. The figures were corrected from the total as printed

Lockport dolomite from Cockburn island formerly used for manufacturing sulphite pulp at Sault Ste. Marie[1].

Insoluble	4·5
Iron and alumina	0·5
Calcium carbonate	52·0
Magnesium carbonate	41·0
Undetermined	2·0
	100·0

Brownish grey, crystalline, Lockport dolomite, Grimsby.[2]

Carbonate of lime	68·92
Carbonate of magnesia	29·48
Carbonate of iron	1·10
Insoluble	0·50
	100·00

Lockport dolomite used in the manufacture of lime at Christie's siding near Kelso, west half of lot 3, concession VI, Nassagaweya township, Halton county[3].

Carbonate of lime		54·12
" magnesia		45·45
" iron		0·58
Sulphate of lime		0·17
Alumina	trace	0·30
Insoluble matter	0·30	
		100·62

Analysis of rock from Ancaster quarries, presumably from the Eramosa beds[4].

Moisture	0·23
Insoluble matter	1·60
Carbonate of lime	53·30
Carbonate of magnesia	43·13

Average of eight samples of rock from lower quarry of Canada Crushed Stone Company at Dundas, representing about 15 feet of upper Eramosa beds. Analysed by Crowell and Murray, mining engineers, Cleveland, Ohio. Analysis furnished by Mr Doolittle, manager of Canada Crushed Stone Company.

Silica	1·66
Iron oxide	0·54
Alumina	0·37
$CaCO_3$	54·42
$MgCO_3$	43·02
Sulphur	0·034
Phosphorus	0·015
	100·059

GUELPH DOLOMITE.

Analysis of average of eight samples of upper 16 to 18 feet of quarry at Dundas, being the lower part of the Guelph formation. Analyses by

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[1] Ont. Bureau of Mines, 1904, pt. II, p. 13.
[2] Geol. Surv., Can., 1876-77, pp. 486-7
[3] Geol. Surv., Can., vol. VIII, 1895, pt. R, p. 17.
[4] Ont. Bureau of Mines, 1903, p. 142.

Crowell and Murray, mining engineers, Cleveland, Ohio, and supplied by Mr. Doolittle, manager of Canada Crushed Stone Company.

Silica	0·41
Iron oxide	0·43
Alumina	0·59
$CaCO_3$	55·20
$MgCO_3$	43·60
Sulphur	0·016
Phosphorus	0·005
	100·251

Analyses of Guelph Dolomite, Wellington County[1].

	I	II
Carbonate of lime	54·25	53·97
" magnesia	45·17	45·37
" iron	0·22	0·16
Sulphate of lime	0·34	0·68
Alumina	trace	trace
Insoluble matter	0·08	0·03
Total	100·06	100·21
(Hygroscopic water after drying at 100° C.)	0·05	0·02

I. Light grey, fine crystalline, massive dolomite from Wellington quarry, south half of lot 29, gore of Puslinch township, Wellington county.

II. Light, cream-yellow, yellowish-brown weathering, very fine crystalline, compact, dolomite, from the priest's quarry on Speed river, Guelph township, Wellington county.

SALINA FORMATION.

Camillus Shale.

Lowest beds exposed in Caledonia gypsum mine. Analysis by Mines Branch, Dept. of Mines, Ottawa.

SiO_2	12·34
Al_2O_3	3·93
FeO	1·94
Fe_2O_3	0·41
CaO	24·20
MgO	16·17
H_2O	3·00
	61·99

CO_2 not determined.

Shale accompanying gypsum at Paris.[2]

Water	0·75
Silica	52·02
Alumina	8·03
Ferric oxide	3·80
Calcium carbonate	9·90
Magnesium carbonate	2·34
Sulphur	1·00

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[1] Geol. Surv., Can., vol. VIII, pt. R, 1895, p. 17.

[2] Ont. Bureau of Mines, 1904, pt. II, p. 34.

Thin limestones, which are interbedded with shale below gypsum horizon at Paris.

Water	0·33
Insoluble	3·32
Calcium oxide	27·77
Magnesium oxide	15·15
Carbonic acid	33·42
Sulphur	0·60

BERTIE-AKRON FORMATION.

Bertie Waterlime.[1]

Rock cut by Welland canal on north end of lot 28, concession II, Humberstone township, Welland county[2].

Fisrt Analysis.

[illegible]	44·68
Mg[illegible]	36·27
Silica, [illegible]d insoluble silicates	16·14
Fe_2O_3 and Al_2O_3	2·46
	99·55

Second Analysis.

SiO_2	12·32
Fe_2O_3, Al_2O_3	4·94
CaO	25·02
MgO	16·80
CO_2	39·13
Moisture	0·06
	98·27

Waterlime at Springvale[3].

Lime	31·58
Magnesia	17·79
Alumina	3·29
Ferric oxide	1·89
Silica	3·69
Water	0·15
Carbonic acid (ignition loss)	44·73

Waterlime, probably Bertie. Bluish, lower rock in quarry on lot 40, concession IV, North Cayuga township, Haldimand county[4].

Water	0·55
Silica	4·14
Alumina	26·60
Ferric oxide	1·56
Calcium oxide	20·09
Magnesium oxide	14·51

Dolomite, probably Akron, occurring below Oriskany sandstone at Michigan Central cut 2 miles east of Hagersville[5].

Water	0·35
Silica	3·44
Alumina	2·34
Ferric oxide	1·86
Calcium oxide	26·61
Magnesium oxide	17·47
Ignition loss	44·96

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[1] Some Akron dolomite may be included

[2] Ont. Bureau of Mines, 1902, p. 34

[3] Ont. Bureau of Mines, 1904, pt. II, p. 118

[4] Ont. Bureau of Mines, 1903, p. 146

[5] Ont. Bureau of Mines, 1903, p. 144

CHAPTE I.

PALÆONTOLOGY: DESCRIPTION OF NEW SPECIES AND PALÆONTOLOGICAL NOTES.

MEDINA-CATARACT FORMATION.

Lingula cuneata Hall.

The original description[1] is as follows: "Shell cuneiform, very acute at the beaks; margins nearly rectilinear, and converging uniformly from near the base to the beak; base slightly curved; the valves convex on the upper half but flattened or compressed towards the base; surface longitudinally striated.

This species is readily distinguished from any of the other species by its acutely cuneata form........but the shell is more or less exfoliated and the striæ partially or wholly destroyed. The shell is translucent and usually of a light colour, particularly in the light grey sandstone......"

From an examination of a quantity of material from the Whitmore quarries, Lockport, N.Y., it is found necessary to modify the above description as follows: on practically every slab examined there are valves of two distinct shapes, the acute form as described above and another form with more obtuse beak. The latter form evidently represents the dorsal valve. A few ventral valves have subparallel sides, the beaks being acute and the general shape cuneiform. A very shallow median septum is present in the ventral valves. This extends from about 2 mm. from the beak to about 5 mm. from the front where it ends in "central scars". The septum is bounded by "concrete laterals" 1 mm. or less apart. The septum and accompanying parts are well illustrated in "Palæontology of New York"[2], This figure also illustrates the less cuneate ventral valves already mentioned. The shell on such parts as are well preserved shows fine radiating striæ, about four to five being spaced in 1 mm. The exfoliated surfaces show fibrous structure, resembling striæ.

The typical shells at Lockport occurring in red sandstone, average: ventral valve 18 to 19 mm. long, 9 to 12 mm. wide at front; dorsal 15 to 18 mm. long, with width as in ventral. In grey sandstone lenses, the length is generally less and the shape less cuneate. At a slightly higher horizon, occurring in highly ferruginous sandstone along with bryozoa and ostrocoda, lingulas are very numerous but are only 7 to 10 mm. long. In other characters they are indistinguishable from the well-developed specimens found not 100 yards away.

At Niagara river, in a 3-foot bed of arenaceous limestone 23 feet above the Whirlpool sandstone, fragmentary lingulas occur; these are typical *L. cuneata*. Twenty-two feet higher up in red sandstone this species of lingula is again abundant, but averages only about 12 mm. in length. The lingulas of the latter horizon are abundant also near Thorold. At Grimsby and Hamilton, lingulas occur in grey sandstone near the top of the Medina section, the beds being older than the true grey band or Thorold quartzite. The lingulas of these localities are of about the same size as those of the upper horizon at Niagara river, but are generally less cuneiform. In all other respects they are similar to the typical *L. cuneata* and there are among them some decidedly cuneate forms. However, Schuchert identifies these as *Lingula clintoni* Vanuxem, formerly known as *L. oblonga*.

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[1] Palæontology of New York, vol. II, 1852, p. 8

[2] Vol. VIII, pt. I, pl. I, fig. 11.

Dalmanella eugeniensis new species.

(Plate VII, figures 1 to 6.)

Shell wider than long, sub-oval more or less, planoconvex, hinge-line shorter than greatest width of shell. Striæ fine, angular, recurved from umbo to lateral margin, increasing by intercalation on dorsal valve and dominantly by bifurcation on ventral valve. One or two well-marked growth lines present near anterior margin of shell. Length of adult specimens from 12 to 18 mm.; width 14 to 22 mm.; thickness 4·6 mm.

Ventral valve moderately convex, flattened toward anterior margin and concave between beak and cardinal-lateral angle; umbo merging into general curvature of shell; beak small, acute, scarcely incurved; cardinal area moderately high, tapering rapidly to cardinal-lateral angles; deltidial plates narrow; pedicle opening wide; hinge teeth large and strong; muscular area short, divided medially by low, rounded elevation.

Dorsal valve nearly flat, with narrow median depression which becomes shallow and ill-defined at front. Beak acute, very short; cardinal area very narrow, cardinal process small trilobed; muscular area about one-third length of shell.

This species closely resembles *Dalmanella elegantula* (Dalman), from which it may be distinguished by being wider than long, having a low broad umbo, cardinal-lateral angles of very little more than 90 degrees, smaller cardinal process, shorter crura, and being generally of larger size.

Occurrence. Cataract formation at Eugenia, Ont., in lower 10 feet of Cabot Head grey shale; at Lavender falls near Dunedin, Ont., in shale partings at top of Manitoulin dolomite; at Hamilton, Ont., in red shaly beds of Grimsby sandstone; near Owen Sound, Ont., along Pottowattomi river in Cabot Head shale just above Manitoulin dolomite.

Dalmanella eugeniensis var *palæoelegantula* Williams n. var.

(Plate VII, figures 7 and 8.)

Small, semi-circular, plano-convex; ventral valve moderately deep, umbo moderately high and narrow, more rounded in younger specimens; cardinal-lateral angles rounded and hinge-line about one-half the width of the shell; dorsal valve nearly flat or gently convex near the beak; a narrow, median groove from beak to front, anteriorly at the bottom of a shallow sinus; length of type specimen 1 cm., width 1 cm., thickness at umbo 3·5 mm.

This variety differs from *D. eugeniensis* in being nearly as long as broad, in having a higher, narrower umbo, and, in the type specimen, in having a narrow, median groove on the dorsal valve. Younger specimens have more convex dorsal valves and lack the median groove.

This variety approaches the characters of *D. elegantula* (Dalman), and hence its variety name; it differs from the later Silurian species, however, in being proportionately wider, in having a lower umbo, and in having a smaller cardinal process and shorter crura.

Occurrence. In Cabot Head shale at Eugenia (collected by J. Stansfield and H. V. Ellsworth 1911), and in Manitoulin dolomite at Glen William.

MEASUREMENTS OF VIRGIANA MAYVILLENSIS AND PENTAMERUS OBLONGUS.

Virgiana mayvillensis Savage, *Cataract Formation.*

	Fitz-william island.	Tama-rack cove.	South bay.	West bay.	Kaga-wong lake.	Helen bay.	Cockburn island.
Specimens examined	4	1	4	2	3	6	5
Smallest	2·1		2·5	1·9	1·9	2 2	2·7 cm. long.
Largest	3·0		3·9	3·0	2·3	3 5	3·5 "
Average	2·5	2·1	3·1	2·4	2·2	2 6	3·1 "
Average ventral septum	0·5	1·7	0·9	0·9	1·1	1·1	0·9
[1]Average ratio	2·8, 2·5	3·5, 4·0	2·4, 2·2	4·8, 4·4	3·7, 2·0	3·2 [illegible]·1	3·1, 2·8

[1]The average ratio is an expression of the quotients obtained by dividing the average lengths and widths of the ventral valves of the specimens successively by the average depth.

Pentamerus Oblongus in Reynales (Clinton) *Dolomite.*

	Rochester.	Thorold.	DeCew falls.	Jordan.	Grimsby.	Kelso.
Specimens examined	5	4	1	2	3	2
Smallest	3·1	2 0	....	2·0	1·7	5·0 cm. long.
Largest	5·7	6·0	......	4·0	5·8	6·2 "
Average	4·5	4·2	3·0	3·0	3·7	5 6 "
Average ventral septum	1·9	2·5		0·2	1·9	2·5 "
Average ratio	3, 2·3	compressed.	1·9, 1·7	1·6, 5·2	5·3, 4·7	2·8, 2·8

Pentamerus oblongus occurs from 1·5 to 2 feet above the base of the Reynales dolomite.

Pentamerus Oblongus in Lockport Dolomite.

	Inglis mills.	Owen Sound	Wiarton.	Barrow bay.	Cabot head, 25 feet up.	Cabot head, near base.	Fossil hill.	Lake Manitou.	Cockburn island.
Specimen examined	4	3	4	8	1	3	2	7	3
Smallest	2·5	5·0	3·7	2·6	....	5·7	3·4	2·2	3·3 cm. long.
Largest	5·5	6 0	5·2	6·0	...	6±	5 +	3·7	8·0 "
Average	4·3	5·5	4 8	4·5	3·5	5·8	4·2±	2·9	5·6 "
Average ventral septum	2·2	3·6	2·6	3·1	2·5	1·8	2·8	1·9	3·0 "
Average ratio	3·9 3·6	4·6 4·3	2·8 2·2	3 2·5	4 3	2·9 2	6·0 5	2·6 2·3	4·3 3·3

Rhynchotreta cabotensis, new species.

(Plate VII, figures 11 a, b, c.)

Shell small, compressed, sub-triangular, not broader than long, valves sub-equally convex. Plications 12 to 14, prominent, rounded, extending from beak to front; separated by interspaces which, at the front, are equal to or greater than the width of the plications. Growth lines prominent near the front only. Length and breadth between 6 and 9 mm., depth 2 to 5 mm., angle between cardinal slopes 70 degrees to 100 degrees or more in some cases.

Pedicle valve moderately convex; beak small, acute, gently incurved, foramen slit extending from the foramen to the contract with the beak of the brachial valve; umbo moderately well defined; median sinus containing two plications confined to the front half of the shell.

Brachial valve slightly more convex than pedicle; beak small; a shallow sinus from the beak to the middle of the shell containing three plications which rise as a low fold at the front of the shell.

The two small figured specimens measure respectively 7 mm. long, 6·5 mm. wide, 2·5 mm. deep; and 6 mm. long, 7 mm. wide, and 2·5 mm deep. The brachial valve of the larger figured specimen, which is of about average size, is 8·5 mm. long, 9 mm. wide, and 2 mm. deep.

R. cabotensis differs from *R. intermedia* Savage in being smaller and less transverse. From *R. lepida* Savage, with which it most closely compares, it differs in the presence of a fold and sinus, and in greater proportional breadth.

Occurrence. In Dyer Bay dolomite and the overlying Cabot Head shale at the "Clay bank" along the shore about 2 miles west of Cabot head.

Atrypa parksi new species.

(Plate VII, figures 19 a, b, c.)

Length and breadth sub-equal. Beak of pedicle valve closely incurved and covering the beak of the brachial valve. Both valves convex, the pedicle with a well-marked sinus in front, not appearing in the umbonal region, and the brachial with a fold, well-marked in front, where the margin of the shell is turned up in some specimens, and only faintly indicated or forming a shallow sinus near the beak. Shell widest posteriorly; cardinal slope varying and extremities rounded. Surface marked by fine rounded plications (5 to 2 mm.) which increase generally by bifurcation and less commonly by implantation and by growth lines which are obscure except near the front of the shell. The specimen chosen as the type measures 24 mm. wide, 18 mm. high, and 10 mm. deep at the umbo. Other specimens are from 13 to 25 mm. in width. Well preserved, small specimens at Credit Forks approach the form of *A. marginalis*, having decided car [illegible] lateral angles, small, prominent, pedicle beaks, and straight frontal margins at the fold.

This species is most closely related to *Atrypa marginalis* Dalman from which it differs in having considerably finer plications, rounded cardinal extremities, less clearly defined fold and sinus, and in being of larger average size.

The species is named after Professor W. A. Parks, of Toronto University, who recognized it as a new species, but left it for the author to describe in this memoir.

Occurrence. In the Manitoulin dolomite at Stoney Creek, Hamilton, Dundas, Credit Forks, Owen Sound, Cabot head, and Church hill, Manitowaning, and West bay, Manitoulin island.

Whitfieldella cataractensis new species.

(Plate VII, figures 16 to 18.)

Elongate oval, moderately convex, rounded, cardinal-lateral angles forming decided "shoulders"; narrow, shallow sinuses on anterior three-fourths of both valves; greatest convexity in posterior third; pedicale valve more convex than brachial; average length 1·7 cm., width 1·3 cm., depth 1·0 cm. A large fairly well preserved specimen measures: length 2·3 cm., width 1·7 cm., and thickness, allowing for crushing, about 1·2 cm. Another specimen doubtfully referred to this species, has no sinus in the brachial? valve, which measures: length 2 cm., width 1·6 cm., depth (one valve) 0·5 cm. Surfaces of the shells are marked by growth lines only.

The number of specimens found is over forty, but many of these are mere fragments, and all are crushed or worn. It is probable that the sinuses have been accentuated by crushing. Among the fragments are remains of some small specimens and also of some large ones that have widths of from 2 to 2·6 cm.

W. cataractensis is most nearly allied to *W. quadrangularis* Foerste, from the Brassfield of Adams county, Ohio. From this species it differs in being smaller on the average, less rotund, and in having more clearly defined and narrower sinuses.

Occurrence. Manitoulin dolomite at Hamilton, Glen William, and Lavender falls; in the arenaceous Manitoulin beds at Niagara river; in limestone lenses in the Cabot Head shales at Stoney Creek, near Owen Sound, and at Credit Forks.

Nuculites (Cleidophorus) cf *ferrugineum* Foerste.

(Plate VIII, figure 4 (small shells).)

Small, elliptical, beak about one-third the distance from the anterior end; a notch and short, narrow sinus in front of the beak. The larger of the two figured specimens is 1·3 cm. long and 7 mm. deep; this is an average specimen. The smaller specimen is 1 cm. long and 0·6 cm. deep.

The above specimens are larger and more elongate than the single specimen figured by Foerste; in other respects there appears to be no difference.

Occurrence. Grimsby sandstone at Kelso, and at "Sydenham road", West Flamborough tonwship, Wentworth county, where it was collected by R. Bell.

Pterinea brisa Hall?

Species represented by left valve. Hinge line about 1·6 cm. in length Greatest radial distance from beaks 1·5 cm.

Valve compressed, oblique. Anterior wing unknown; posterior wing distinctly separated from body and terminated in an angle of more than 90 degrees. The most distinctive character of this species is the presence of five, close set (1 mm. apart), wavy lines of growth on the body of the shell. The undulations are about 1 mm. in amplitude. On the posterior wing the lines of growth are curved, with convex side forward.

Another specimen, probably belonging to this species, is decidedly convex, measures 1 cm. on the hinge line, and 1 cm. in length. It has fine, radiating striæ about three in 1 mm. and has three decided growth lines, 1·5 mm. apart, on the anterior half of the shell.

In outline this species resembles *P. elegans*, Savage.

Locality. Grimsby sandstone, at Kelso, Ont.

Pterinea cf *undata* (Hall).

(Plate VIII, figure 2.)

Left valve observed: oblique, moderately convex, length of hinge line about 2·5 cm.; greatest radial length from beak 3 cm. Anterior wing rounded, separated from body of shell by a shallow sinus situated about one-third the distance from the anterior to the posterior extremity. Posterior wing not distinctly separated from the body of the shell, and not extending beyond length of shell. Hinge line making obtuse angles with outline of shell at both extremities. Umbo extending slightly beyond hinge line. Surface marked by growth lines and striations, two to three in 1 mm., the striations being seen only near the centre of the shell in this specimen.

Two small specimens measure, respectively: hinge line 1·4 cm., length 1·4 cm.; and hinge line 1·2 cm., length 1·4 cm. The broader shows faint traces of radiating striæ, and both show growth lines, the broader approaching *P. undata* in characters.

This species resembles *P. undata* Hall closely in outline, but differs from it in surface markings which may, however, be exfoliation characters only. It corresponds closely with the fragment figured by Hall, "Palæontology of New York", volume II, 1852, Plate 4, bis, figure II d and e. These figures have been removed from *Modiolopsis primigenus* where Hall placed them, by Bassler[1] who has not identified them. Figure IIe (Hall) compares with this species in outline, but is a left valve, and being convex is probably not a *Pterinea*. Hall's specimens were from the Medina sandstone at Medina.

Occurrence. Grimsby sandstone, Niagara gorge south of Lewiston, N.Y.

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[1] U S Nat. Mus. Bull. 92, vol. II, p. 819

Modiolopsis Kelsoensis new species.

(Plate VIII, figure 3.)

Shells oval, and moderately convex: beak about one-third the distance from the front of the shell; a shallow but well-marked sinus from the centre of the beak downward and somewhat backward to the base of the shell; marked growth lines over the entire surface; hinge area not seen; length of type 3·5 cm., depth 1·5 cm., thickness, including both valves, about 1·4 cm.

Occurrence. In red Grimsby sandstone at Kelso, and on lot 11, concession 1, West Flamborough, Wentworth county. The latter locality is represented by a specimen collected by R. Bell and formerly labelled *Grammysia Canadensis* Billings (see figures).

Lophospira pulchra new species.

(Plate VII, figures 22a, b.)

Shell conic, slightly wider than high. Height 17 mm., width 15 to 16 mm., apical angle about 85 degrees, volutions 4, slit band prominent; a well-marked keel present on all volutions above slit band, about halfway between slit band and suture. Suture impressed, younger volutions overlapping on older about half-way to slit band, which is centrally located. Surfaces between slit band, keel, and suture, and slit band and suture, concave. Lower surface of last volution subventricose. Fine striations, directed somewhat backward, cross the surfaces from the suture downwards to slit band, being undisturbed by the keel. From the slit band to the suture below they are directed forwards. Aperture unknown.

Occurrence. At Cataract, in flint nodules in lower 6 feet of Manitoulin dolomite. Collector, J. Stansfield, 1912. Only one specimen is known to the writer.[1]

Observation. This species is very similar to *L. bispiralis* (Hall), of the Guelph formation, from which it differs, however, in being somewhat lower and consequently having a larger apical angle and in having the keel above the slit band persistent on all the volutions including the outer one.

Pleurotomaria species.

One specimen was found by the writers' assistant, H. V. Ellsworth, at the top of the Whirlpool sandstone, in a small gully near the cement tunnel over the New York Central tracks, south from Lewiston, New York. This specimen is fragmentary and about two-thirds the size of Hall's figured specimens of *P. littorea.* It is also proportionately lower. In other respects it corresponds with this species.

A number of casts of small gastropods occur in the upper beds of Whirlpool sandstone at Glen William, Ont. They appear to be all of one species and correspond closely to *H. subulata* as described and illustrated. They, however, show faint, but distinct "peripheral angulation and band" and so differ from *H. subulata* as so far known (Plate VIII, figure 1).

---

[1] A small undetermined species of Lophospira, about 4 mm. in height and greatest diameter, occurs in the same chert nodule.

ROCHESTER FORMATION.

Strophonella decewensis new species.

(Plate XIII, figure 1.)

Brachial valve, semi-oval, longer than broad, moderately conve broadest and most convex near the centre; lateral areas in front of th hinge-line concave, area in front of beak flattened and containing a shor narrow sinus; striæ fine, rounded, and curved backward near the hing line, number about 100, increasing by implantation; hinge-line less th width of shell; cardinal-lateral angles rounded. Length 3·4 cm., widt 3·2 cm. **Pedicle valve not seen.**

This species differs from *S. patenta* in having greater length than widt and rounded, cardinal-lateral angles.

Occurrence. Rochester shale, 8 to 12 feet below the top at DeC falls near Power Glen, Lincoln county, Ont.

LOCKPORT FORMATION.

Stricklandinia manitouensis new species.

(Plate XX, figures 2, 3.)

Longer than wide, very convex; valves nearly equal; greatest co vexity in posterior portion of shell; a faint sinus in the pedicle valve a a faint fold on the brachial valve; simple, rounded, radiating striæ, ab five in 5 mm. at the front of the shell; median septum about 3 to 4 m in length. The beaks are worn in all three specimens in hand, but t beaks of both valves are evidently short, the pedicle closely incurved o the brachial. The following measurements are only approximate ow to the worn condition of the specimens: No. 1, length 2·5 cm., wi 2·1 cm., thickness 1·8 cm.; No. 2, length restored about 3 cm., wi 3·2 cm., thickness 1·5 cm.; No. 3, length 3 cm., width 2·6 cm., th ness 1·9 cm.

This species is thicker and narrower than *S. deformis* Meek and Wort and lacks the growth lines of that species. It compares most closely w *S. norwoodi* Foerste, from the figures of which it differs in having the and sinus less marked, and in having more clearly marked striations. a tendency to greater rotundity.

Formation and Locality. Lockport dolomite, Fossil Hill horizon plateau east of Sandfield, Manitoulin island.

GUELPH FORMATION.

Orthoceras brucensis, new species.

(Plate XXVI, figures 1 a, b.)

Straight, gently tapering, about 2½ mm. in the space of one diam surface marked by oblique annulations, about four in the width of segment; cross-section circular, siphuncle about half-way between c and circumference; diameter 1·2 to 2·7 cm. Camaræ deep, in the shape of short cones terminated by hemispheres, thickness unusual, 1·5 to 1·7 mm. The centres of the camaræ weather out so as to leave only the walls preserved, the result suggesting double camaræ.

This species is very similar to *O. unionense* Worthen, but differs in having deep, thick camaræ.

Occurrence. Guelph dolomite on Bruce peninsula at Hay bay, 3 miles west of Tobermory, at Dorcas bay and Baptist harbour near Cape Hurd, and in Lockport dolomite about 15 feet above the base at Limehouse, Ontario.

APPENDIX I.

NEW SPECIES OF BRACHIOPOD.

(*By A. F. Foerste.*)

Rhynchotreta Williamsi new species.

(Plate VII, figures 15 a, b.)

This species is closely related to *Rhynchotreta thebesensis* Foer-
from which it differs chiefly in the absence of any tendency toward th
elevation of the two median plications of the brachial valve, and a co
responding depression for the median plication of the pedicle valve. Ap
parently, the plications are much less distinct and the beak of the ped
valve is more strongly incurved, but it is not certain whether these diffe
ences are not due in part to the state of preservation of the single specim
here described as *Rhynchotreta williamsi*. In this specimen, the plicati
are distinct only near the anterior margin and are nearly obsolete posterio
The specimen was obtained, however, in a dolomitic rock and may be
of those casts partaking more of the interior characters of the species th
of its exterior surface features. Eleven or twelve plications may
distinctly recognized along the anterior margin of the shell, in additio
which two or three plications are faintly indicated on each of the flatt
sides.

Rhunchotreta williamsi was found in the Manitoulin dolomite, at
2 miles southeast of Manitowaning, on Manitoulin island, where
dolomite forms a conspicuous hill, south of the road to South bay. Th
species is named in honour of M. Y. Williams, with whom the writer
the pleasure of visiting the locality in question.

Rhynchotreta thebesensis was found in the Edgewood limesto
division of the Medina, at Thebes, Illinois.

APPENDIX II.

NEW SPECIES OF CRINOID

(*By Frank Springer*)

Eucheirocrinus Ontario new species

An imperfect specimen, the only one found in rocks of this formation, its geological position being older than that of *E. chrysalis* (Hall), and *E. radiculus* (Ringueberg), both from the Rochester shales. Enough is preserved, however, to show the essential characters on which the species is based, which are:

The left anterior ray (="dorsal arm") bifurcates on the third plate above the radial, and on every third brachial above that, by equal branches; thus it has three primibrachs. The left posterior ray has only two primibrachs, bifurcating unequally on the second, and on every second plate above that. The two segments of the left anterior radial are in contact, the inferior segment being a wide plate for its entire length, with parallel sides. These characters are shown in Figure 6.

The species differs from *E. chrysalis* and *E. radiculus*, from Lockport, in the much smaller number of primibrachs in the dorsal arm, those species having seven to nine or more; and in the greater width and more rectangular form of the inferior segment of the radial. In the former respect it resembles a species from the Wenlock formation at Dudley, England, which has only one primibrach (perhaps "*Cheirocrinus*" *serialis* Salter, a vague name). In the latter it is somewhat comparable to *E. barrandei* Walcott, from the Trenton of New York, and recalls the very wide corresponding plate in *Cremacrinus*.

Occurrence. Manitoulin bed, Cataract formation, Stoney Creek, Ontario

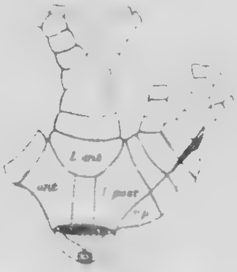


FIG. 6. *Eucheirocrinus* [illegible]
Diagrammatic view. [illegible]
2 diameters. G.S.C.
[illegible] No. 430

APPENDIX III.

NEW SPECIES OF CORAL.

(*By George H. Chadwick.*)

Family *Columnariidæ.*

Genus *Palæophyllum* Billings.

Palæophyllum (*Cyathophylloides?*) *williamsi* sp. nov.

(Plate V, figure 2.)

Corallum composite, sub-fasciculate; corallites cylindrical; the new corallites interspersed among the older, from 1½ mm. up to rarely 6 mm. in diameter; the mature corallites averaging about 4 mm. Gemmation appears to be lateral and fairly prolific. Outer wall strong; exterior surface slightly undulate and with septal striæ; a strongly wrinkled epitheca like that of *Cyathaxonia cynodon* is preserved at a few points on the holotype. Septa usually about eighteen to twenty-four in adult corallites, not reaching the centre, rather strong and regularly arranged but occasionally very slightly twisting or curving; in addition, short, interstitial septa alternate with the long ones but are in many cases rudimentary. The central area is well-like and has a diameter varying from nearly equal to the length of the long septa to less than half that amount. The tabulæ vary from strongly convex to flat or even concave in the centre with the periphery curved down, and are spaced from 1 to 2 mm. apart; they do not interrupt the longer septa. No dissepiments nor fossula. Type specimen collected by M. Y. Williams from the Manitoulin dolomite east of Manitowaning bay, Manitoulin island.

Observations. This appears to be the species most likely to be identified as "*Diphyphyllum multicaule*" in the Cataract formation. The habit of growth is exactly that of *Synaptophyllum* except for the absence of the connecting processes, but the internal structure is wholly different, being that of *Columnaria.* The composite rather than compound mode of growth would appear, however, to be of generic value.

This species differs from *Palæophyllum stokesi* (Edwards and Haim of the Richmond, by its smaller corallites and more widely spaced tabula also in the entire absence of the connecting processes mentioned by Edward and Haime and figured by Whiteaves. In its mode of growth and arrange ment of tabulæ it is still less like the Richmond genotype, *P. rug* Billings (as figured by Lambe), which is clearly distinct specifically from *P. stokesi.* Much more closely allied is *Palæophyllum thomi* (Hall Texas. This last is referred by Walcott to *Cyathophylloides* Dybowsk whose typical species supposedly include *C. rhenanus* Frech and *C. d junctus* (Whiteaves) of the Devonian. Should this reference prov appropriate, perhaps in a subgeneric sense as used by Whiteaves, it w carry with it the other two thick-walled species which do not underg polygonal compression, *P. williamsi* and *P. stokesi*. The corallites in *P. williamsi* are more variable in size than shown for *P. thomi* and have not the peculiar structure in transverse section represented in Hall's figures, but comparison with actual specimens may leave few real distinctions.

Palæophyllum umbellicrescens sp. nov

Corallum subcompound, usually small, subastraeiform. Corallites closely set, subparallel or radiating, tapering cylindrical or becoming polygonal toward the base by mutual compression, varying from $\frac{2}{3}$ to 3 mm. in diameter, the mature polyps being seldom under $2\frac{1}{2}$ mm. Epitheca well marked, obscuring the septal grooves where not weathered away. Tabulæ convex, numerous and complete, spaced $\frac{1}{2}$ to $\frac{2}{3}$ mm. apart, not interrupting the septa. Septa short, the alternate ones reaching about half-way to the centre, in some cases a little more; the longer septa, about twelve in number in mature corallites, regularly arranged, with as many intermediate ones.

When a corallite reaches maturity (3 mm.) the inner ends of the longer septa become united in a continuous ring, like an inner wall, thus producing a whorl of marginal chambers each with a single septum (the short intermediate one). These calices immediately assume a circular form, remaining in contact laterally, and new septa rapidly appear as the growing corallite enlarges upward. By crowding the circular arrangement is soon lost, but the umbels spring again with considerable regularity, simultaneously from each corallite, after from 15 to 20 mm. of upward growth.

The type specimens (six in number) were collected by M. Y. Williams from "The Rock", and a seventh specimen was obtained by M. Y. Williams from the "Devil's Needle", both localities being near Manitowaning, Manitoulin island. Formation, Manitoulin dolomite.

Observations. The more closely aggregated corallites, closer tabulæ and thin wall, ally this species with the genotype, *P. rugosum* Billings of the Richmond, from which and from *P. calcinum* (Nicholson) its small size and fewer, shorter septa at once distinguish it. The peculiar mutiplication by septal gemmation in marginal whorls as in *Romingeria* has not previously been remarked in *Columnaria* or *Palæophyllum*, and may prove of subgeneric value.

PLATE II.

Medina-Cataract Fossils.

Fucoid (natural size.)

Green grey, argillaceous sandstone at top of Whirlpool sandstone, Glen William, Ont. G.S.C., Mus No. 4386. (Page 26.)

PLATE II.

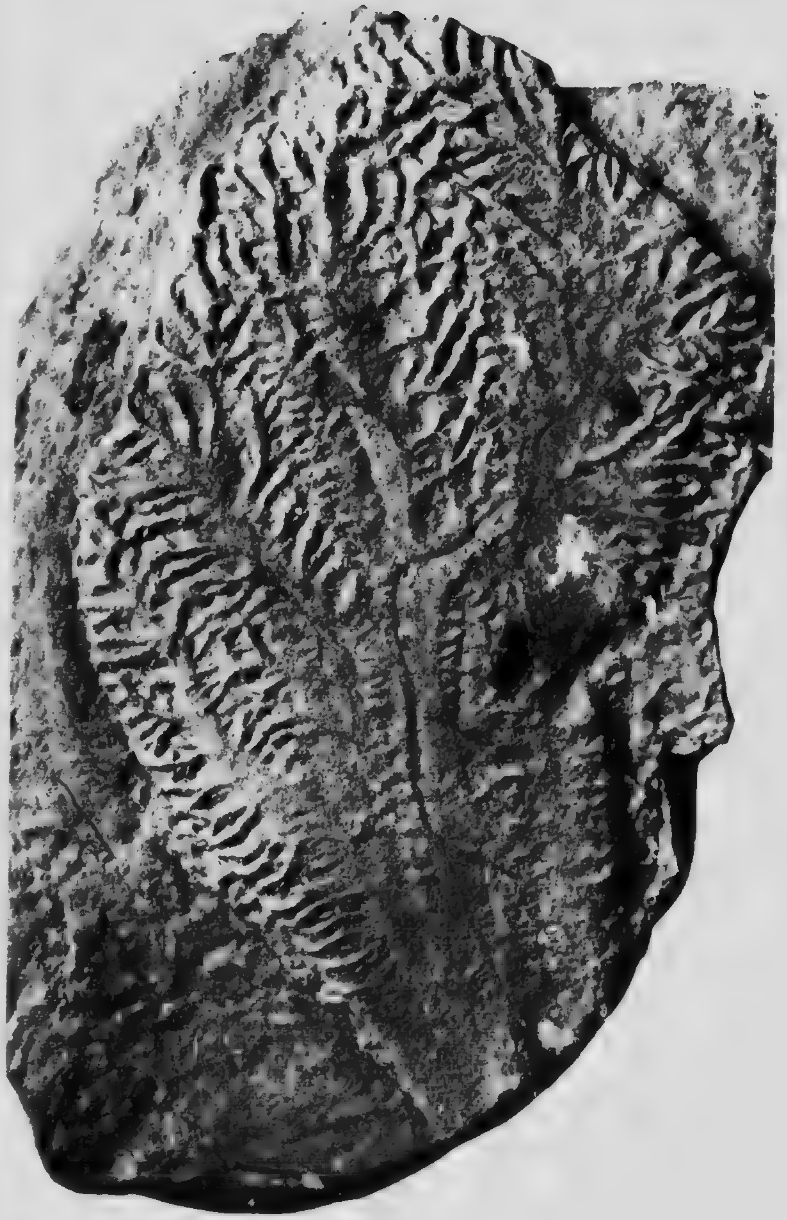


Plate III.

Medina-Cataract Fossils.

(Figures natural size.)

Figure 1. Fucoids in grey, impure dolomite at base of Manitoulin dolomite, Glen William, Ont. G.S.C., Mus. No. 4504. (Page 29.)

Figure 2. Worm burrows. Greenish white sandstone, top of Whirlpool sandstone. Glen William. Ont. G.S.C., Mus. No. 4505. (Page 26.)

PLATE III.

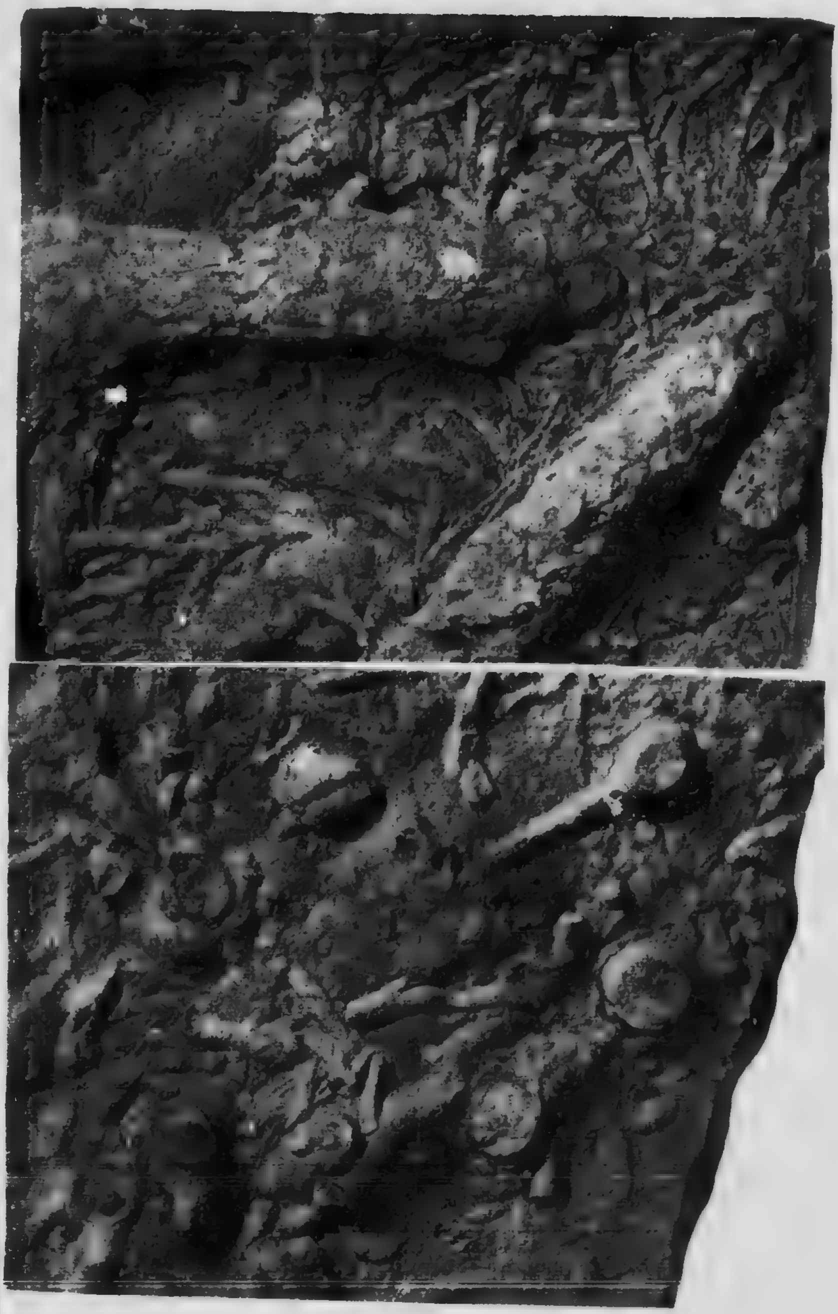


PLATE IV.

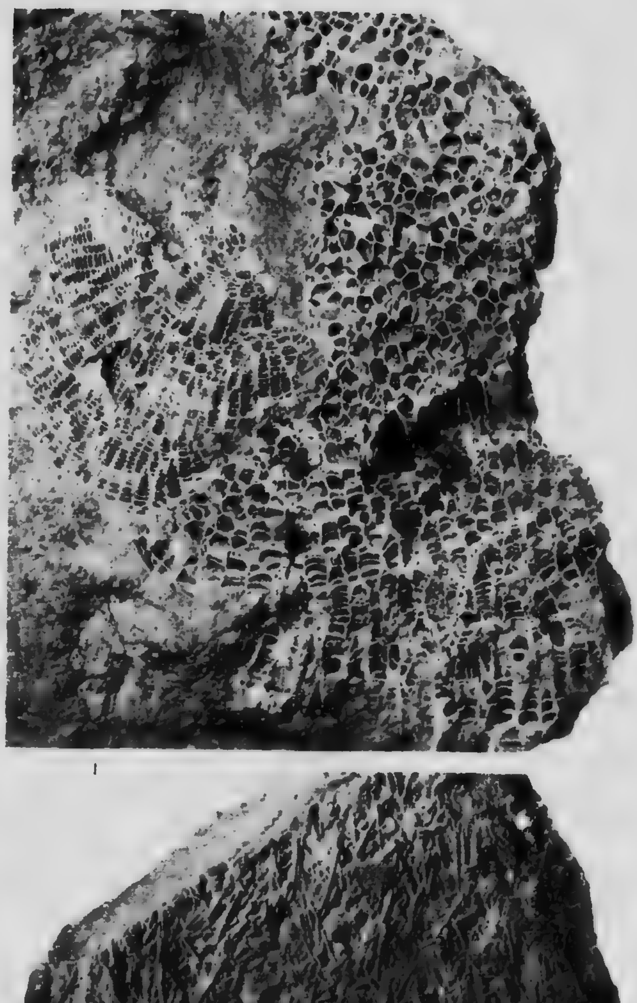
Medina-Cataract Fossils.

(Figures natural size.)

FIGURE 1. *Favosites cristatus* Edwards and Haime, St. Edmund dolomite at Cabot head. G.S.C., Mus. No. 4506. (Page 38.)

FIGURE 2. *Helopora fragilis* Hall. Grey dolomite lens in Cabot Head shale, Stoney Creek, Ont G.S.C., Mus. No. 4507. (Page 35.)

Plate IV.



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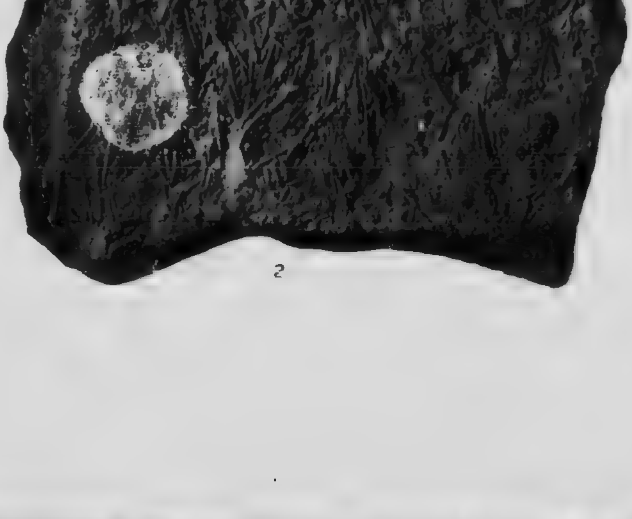


2

PLATE V.

Medina-Cataract Fossils.

(Figures natural size.)

FIGURE 1. *Receptaculites canadensis* Billings' type. Fine-grained lens of dolomite in Cabot Hea shale, Limehouse, Ont., Collector, R. Bell. G.S.C., Mus. No. 2590. (Page 35.)

FIGURE 2. *Synaptophyllum williamsi* Chadwick n. sp. Manitoulin dolomite east of Manitowanin bay, Manitoulin island. G.S.C., Mus. No. 4508. (Page 128.)

FIGURE 3. *Acervularia gracilis* (Billings). Manitoulin dolomite, Manitowaning bay, Manitoul island. G.S.C., Mus. No. 4503. (Pages 30 and 31.)

FIGURE 4a. *Enterolasma cf. geometricum* (Foerste). Manitoulin dolomite, near Ice lake, Manitoul island. G.S.C., Mus. No. 4511. (Pages 30 and 31.)

FIGURE 4b. Calyx of 4a.

FIGURE 5. *Streptelasma cf. hoskinsoni* Foerste. Manitoulin dolomite, near Ice lake, Manitoul island. G.S.C., Mus. No. 4512. (Pages 30 and 31.)

FIGURE 6a, b; 7a, b. *Brockocystis tecumseth* (Billings). Manitoulin dolomite, near Ice lake, Ma toulin island. G.S.C., Mus. No. 4516, 4516a. (Pages 30 and 31.)

FIGURE 8. *Favosites cristatus* Edwards and Haime. St. Edmund dolomite, Centre bluff, Ca head. G.S.C., Mus. No. 4513. (Page 38.)

PLATE V.

Cabot Head

Manitowaning

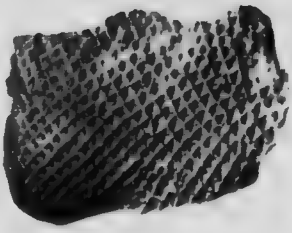
, Manitoulin

ke, Manitoulin

e, Manitoulin

ce lake, Mani-

bluff, Cabot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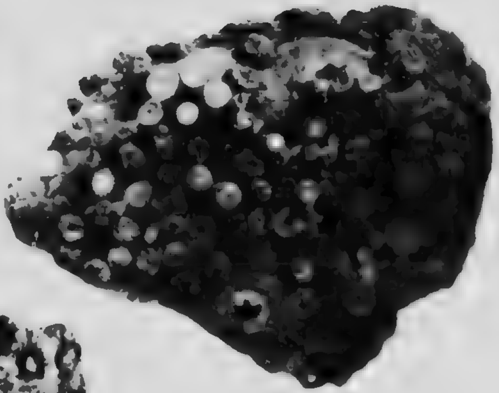
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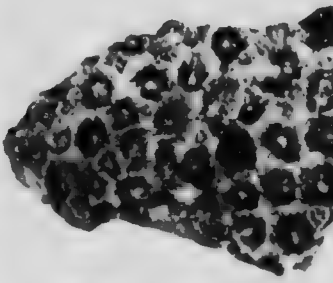
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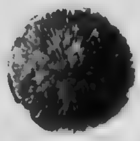
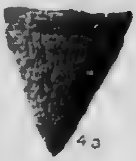
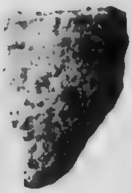

4 b


4 a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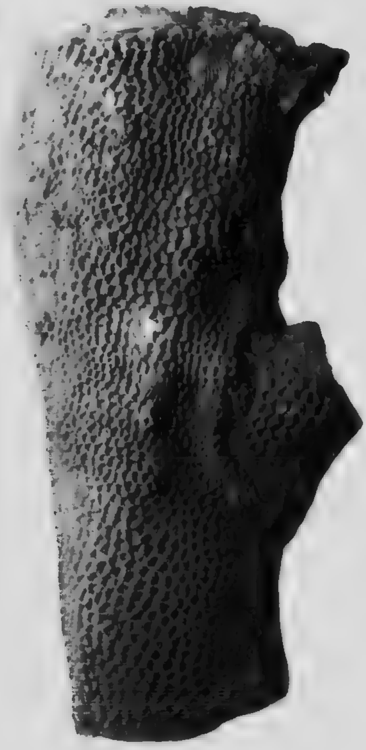
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6

7 b

6 a

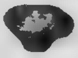
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PLATE VI.

Medina-Cataract Fossils.

Charateristic fossils of Manitoulin dolomite.

(Figures natural size excepting 1b.)

FIGURE 1a. *Paleofavosites asper* D'Orbigny. Manitoulin dolomite, near Ice lake, Manitoulin island. G.S.C., Mus. No. 4514. (Pages 30 and 31.)

FIGURE 1b. A natural section of Figure 1a, enlarged X 2. (Pages 30 and 31.)

FIGURE 2. *Strophonella striata* (Hall). Manitoulin dolomite, Lavender falls, Ont. G.S.C., Mus. No. 4623. (Pages 30 and 31.)

FIGURE 3. *Orthis flabellites* Foerste. Manitoulin dolomite, Lavender falls, Ont. (Pages 30 and 31.

FIGURE 4a. *Platystrophia biforata* (Schlotheim), brachial valve. Cabot Head shale, just above Manitoulin dolomite, Eugenia falls, Ont. G.S.C., Mus. No. 4517. (Pages 30 and 31.)

FIGURE 4b. Frontal view of Figure 4a. (Pages 30 and 31.)

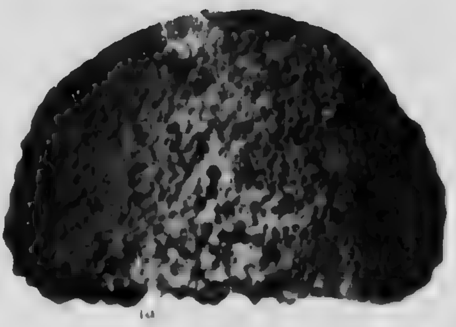
FIGURE 5a. *Cælospira planoconvexa* (Hall), brachial valves. Manitoulin dolomite, near lake Manitou. G.S.C., Mus. No. 4518. (Pages 30 and 31.)

FIGURE 5b. *Cælospira planoconvexa* Hall, frontal view. Locality same as Figure 5a. (Pages and 31.)

FIGURE 5c. Pedicle valve of Figure 5b. (Pages 30 and 31.)

FIGURE 6. Pedicle valve of *Leptæna rhomboidalis* (Wilckens). Manitoulin dolomite from Blue mountain 5 miles west of Collingwood. G.S.C., Mus. No. 4520. (Pages 30 and 31.)

PLATE VI.



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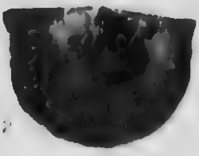

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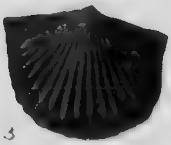

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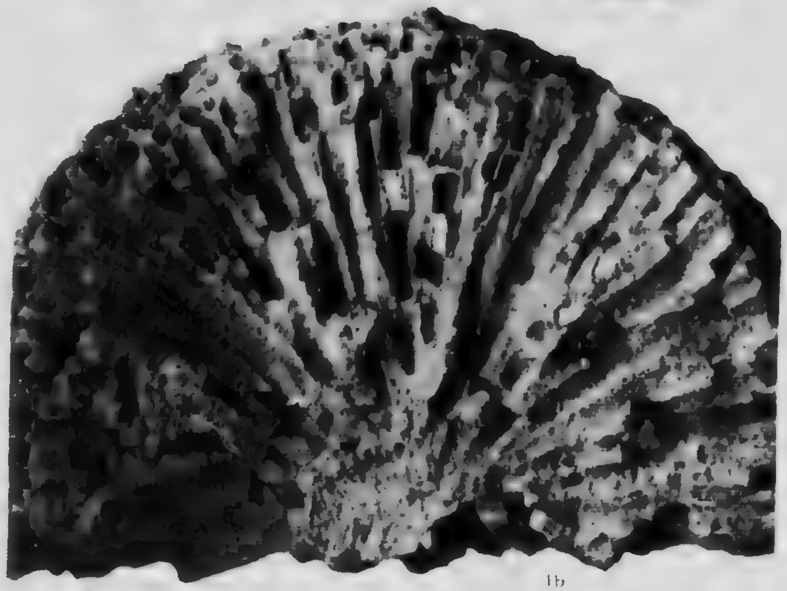
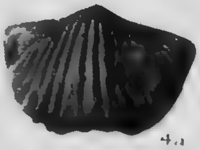
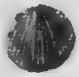


1b



4a



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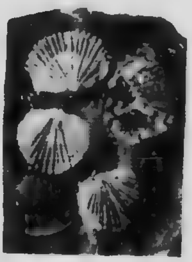
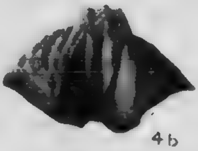
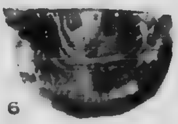
5b



5a



4b



6

PLATE VII

Medina-Cataract Fossils

(Figures natural size)

FIGURE 1. *Dalmanella eugeniensis* n. sp., pedicle valve. Manitoulin dolomite, Lavender falls, Ont. G.S.C., Mus. No. 4521. (Page 118)

FIGURE 2a, b. *D. eugeniensis*, pedicle and frontal views of small specimen. Occurrence same as last. G.S.C., Mus. No. 4521a. Page 118

FIGURE 3a, b, c, d. *D. eugeniensis*, pedicle, frontal, brachial, and cardinal views of small specimens. Cabot Head shale, Eugenia. G.S.C., Mus. No. 4522. (Page 118

FIGURE 4. *D. eugeniensis*, interior of pedicle and brachial valves, which are attached by rock. Manitoulin dolomite, Lavender falls. G.S.C., Mus. No. 4521b. Page 118

FIGURE 5. *D. eugeniensis*, interior brachial valve. Cabot Head shale, 10 feet above Manitoulin dolomite, Eugenia. G.S.C., Mus. No. 5218. Page 118

FIGURE 6. *D. eugeniensis*, interior pedicle valve. Locality same as Figure 5. G.S.C., Mus. N 4522a. Page 118

FIGURE 7a, b. *Dalmanella eugeniensis* var. *palmato-pustula* n. var., pedicle and brachial valv Cabot Head shale, Eugenia. G.S.C., Mus. No. 4601. Page 118

FIGURE 8a, b. *D. eugeniensis* var. *palmato-pustula*, brachial and cardinal views. Cabot Head shal Eugenia. G.S.C., Mus. No. 4602. Page 118

FIGURE 9a. *Rhipidomella hybrida* (Sowerby), cardinal views. Cabot Head shale, Eugenia. G.S.C., Mus. No. 4617. (Page 35

FIGURE 9 b. Pedicle valve of 9a. (Page [illegible]

FIGURE 10a, b. *Camarotoechia neglecta* Hall, brachial and frontal views. Cabot Head shal Eugenia. G.S.C., Mus. No. 5219. [illegible]

FIGURE 11a, b, c. *Rhynchotreta cabotensis* n. sp., brachial, frontal, and pedicle views. Cabot He shale at top of Dyer Bay dolomite, Clay cliff, near Cabot head. G.S.C., Mus. No. 46 (Page 129.)

FIGURE 12. *Rhynchotreta* cf. *lepida* Savage, brachial view. Cabot Head shale just above Dyer Ba dolomite, Clay cliff, near Cabot head. G.S.C., Mus. No. 4624. (Page 35.)

FIGURE 13a, b. *R.* cf. *lepida*, pedicle and brachial views, small specimen. Locality same as Figur 12. G.S.C., Mus. No. 4626b. (Page 35.

FIGURE 14. *R.* cf. *lepida*, a narrow specimen. Locality same as Figure 13. G.S.C., M 4626a. (Page 35.)

FIGURE 15a, b. *Rhynchotreta williamsi* Foerste, n. sp., pedicle and lateral views. Manit mite, Manitowaning bay, Manitoulin island. G.S.C., Mus. No. 4331. (Page 12

FIGURE 16a, b. *Whitfieldella cataractensis* n. sp., brachial and lateral views. Cabot He near Owen Sound. G.S.C., Mus. No. 4627 Page 121

FIGURE 17, a, b, c. *W. cataractensis*, brachial, pedicle, and lateral views. Cabot Hea Stoney Creek. G.S.C., Mus. No. 4628. (Page 121

FIGURE 18. *W. cataractensis*, pedicle view of another from Stoney Creek. G.S.C., Mus. No. 46 (Page 121.)

FIGURE 19a, b, c. *Atrypa parksi* n. sp., brachial, pedicle, and frontal views. Cabot Head shale Credit Forks. G.S.C., Mus. No. 4673. (Page 120.)

FIGURE 20. *Virgiana mayvillensis* Savage, pedicle valve. Dyer Bay dolomite, South bay, M toulin island. G.S.C., Mus. No. 4674. (Page 37.

FIGURE 21. *Virgiana mayvillensis* Savage, pedicle valve. Dyer Bay dolomite, Tamarack cove. Manitoulin island. G.S.C., Mus. No. 4675. (Page 37

FIGURE 22a, b. *Lophospira pulchra* n. sp. Manitoulin dolomite, Cataract, Ont. G.S.C., Mus No. 4678. (Page 123.

FIGURE 23. *Strophostylus* cf. *cyclostoma* Hall. Manitoulin beds, Jordan, Ont. G.S.C., Mus. No 4679. (Page 28.)

11

PLATE VII

PLATE VIII.

Medina-Cataract Fossils.

(Figures natural size.)

FIGURE 1. *Hormotoma subulata* (Conrad)?? Top of Whirlpool sandstone, Glen William, Ont. G.S.C., Mus. No. 4680. (Page 28.

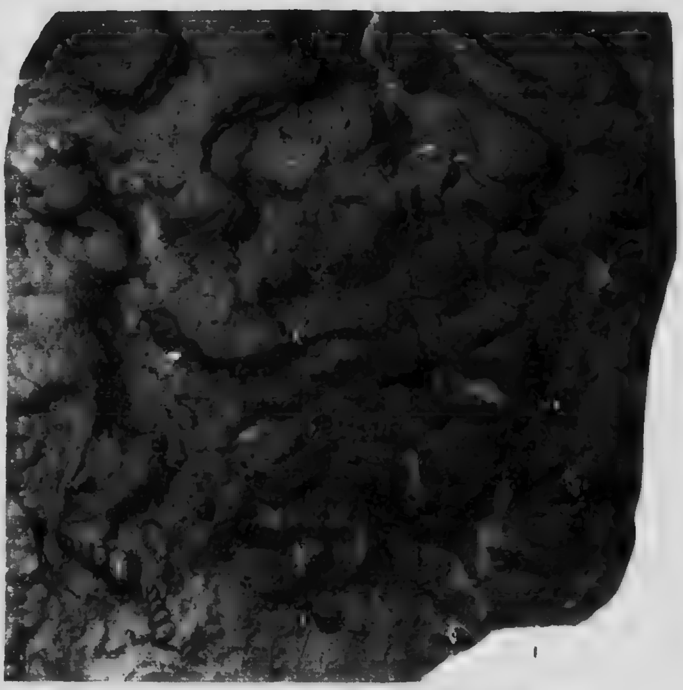
FIGURE 2. *Pterinea* cf *undata* (Hall). Grimsby, red argillaceous sandstone, Flamboro, Wentworth county, G.S.C., Mus. No. 2703. (Pages 40 and 122.)

FIGURE 3. *Modiolopsis kelsoensis* n. sp. "Iron band" horizon of Grimsby sandstone near Kelso, Ont. G.S.C., Mus. No. 4681. (Pages 49 and 123.)

FIGURE 4. *Ctenodonta machæriformis* (Hall) and *Nuculites* (*Cleidophorus*) cf *ferrugineum* Foerste Red Grimsby sandstone, Flamboro West. G.S.C., Mus. No. 2708. (Page 40.)

FIGURE 5. *Modiolopsis kelsoensis.* Grimsby sandstone, lot 11, concession I, Flamboro West, G.S.C., Mus. No 2709. (Pages 40 and 123.)

PLATE VIII.



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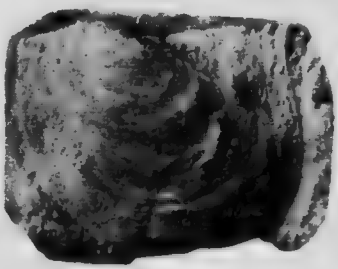

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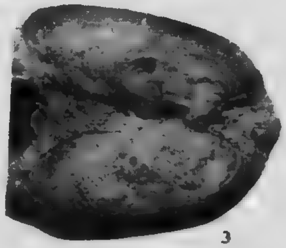

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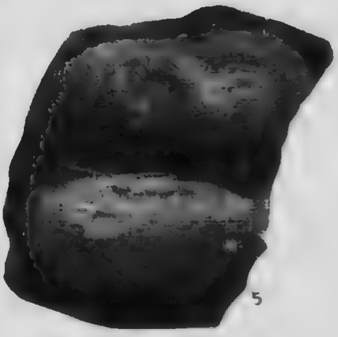

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PLATE IX.

Clinton Fossils.

Figures natural size.

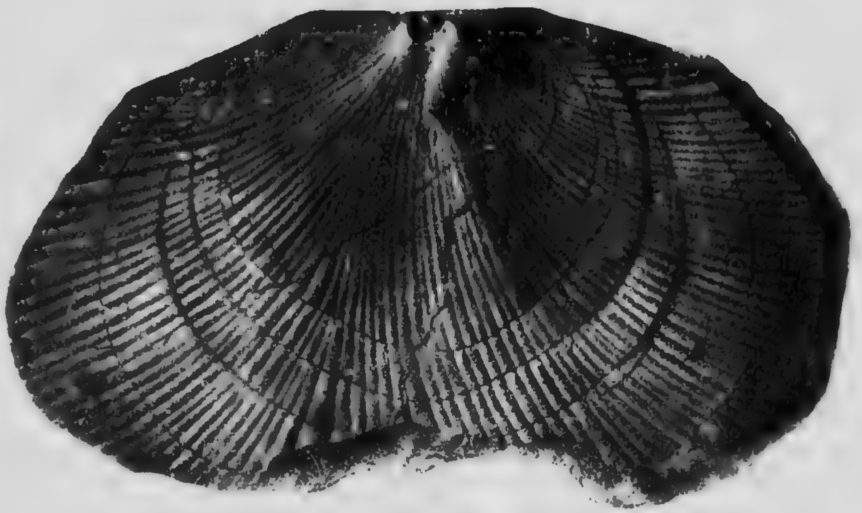
FIGURE 1. *Stricklandinia canadensis* Billings, pedicle valve. Reynales (Wolcott) dolomite Thorold. After Palæozoic fossils, vol. II, pt. 1, pl. 6, fig. 3. (Page 49.)

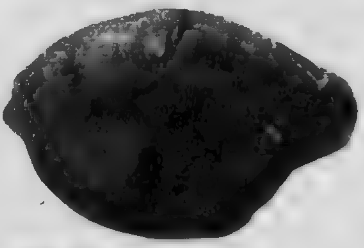
FIGURE 2. *Stricklandinia canadensis* Billings, cardinal view. Top of Reynales (Wolcott) dolomite Grimsby, Ont. G.S.C., Mus. No. 4684. (Page 49.)

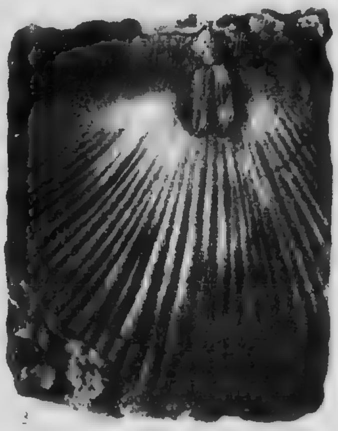
FIGURE 3. *Stricklandinia canadensis* Billings, brachial valve. Reynales (Wolcott) dolomite After Palæozoic fossils, vol. II, pt. I, pl. 6, fig. 2. (Page 49.)

FIGURE 4. *Buthotrephis gracilis* var. *crassa* (Hall). Reynales (Wolcott) dolomite. After Palæontology of New York, vol. II, pl. 5, fig. 3a. (Page 49.)

PLATE IX.







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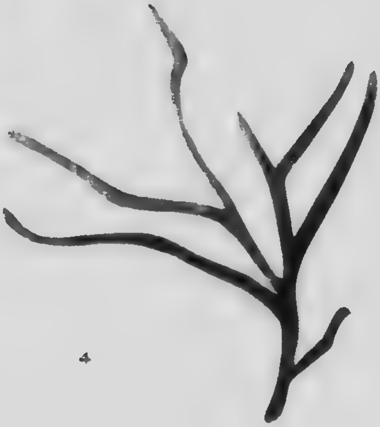

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PLATE X.

Clinton Fossils.

(Figures natural size except 7b.)

FIGURE 1. *Spirifer radiatus* (Sowerby) Reynales (Wolcott) and Irondequoit dolomites. After Palæontology of New York, vol. II, pl. 22, fig. 2f. (Page 49.)

FIGURE 2. *Hyattidina congesta* (Conrad). 2a, brachial, 2b, frontal, views. Reynales (Wolcott dolomite. After Palæontology of New York, vol. II, pl. 23, figs. 2c and 2d. (Page 49.)

FIGURE 3. *Cœlospira hemispherica* (Sowerby). 3a, pedicle, and 3b, brachial, valves. Sodus shale. After Palæontology of New York, vol. VIII, pt. II, pl. 82, figs. 2 and 3. (Page 48.)

FIGURE 4. *Whitfieldella cylindrica* (Hall). 4a, brachial, 4b, lateral, views. Irondequoit dolomite. After Palæontology of New York, vol. II, pl. 24, figs. 2a, 2c. (Page 51.)

FIGURE 5. *Whitfieldella intermedia* (Hall). 5a, brachial, 5b, lateral, views. Reynales (Wolcott and Irondequoit dolomites. After Palæontology of New York, vol. II, pl. 24, figs. 3a, 3b. (Page 49.)

FIGURE 6. ***Rhynchotreta robusta*** (Hall), pedicle valve. Irondequoit dolomite. After Palæontology of New York, vol. II, pl. 23, fig. 7a. (Page 51.)

FIGURE 7. *Tentaculites minutus* Hall. 7a, specimens natural size; 7b, magnified about four times. Reported from "lower Clinton" of Clinton, N.Y., by Hall. After Palæontology of New York. vol. II, pl. 41a, figs. 8b, c. (Page 55.)

PLATE X.

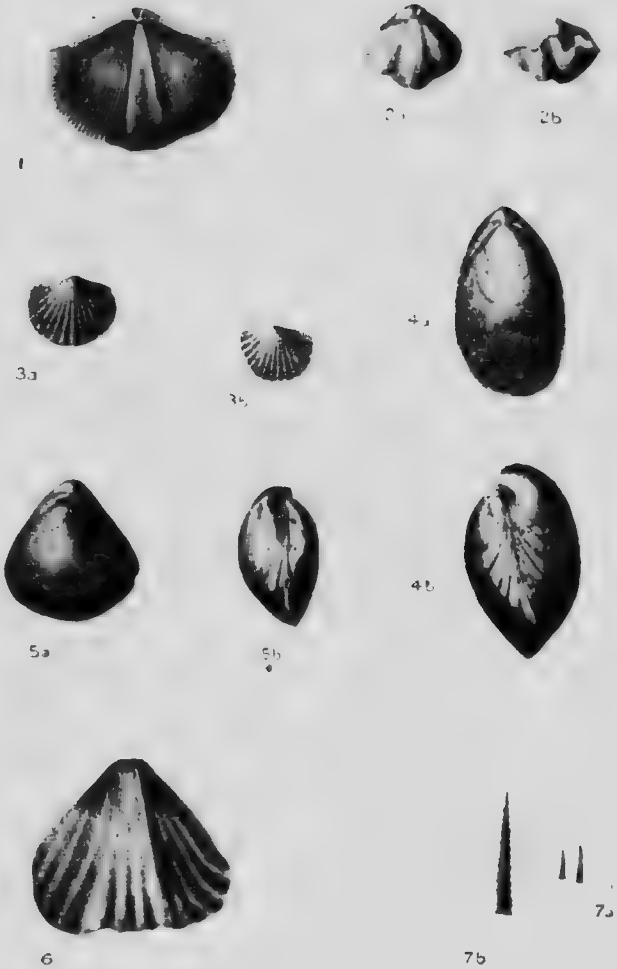


PLATE XI.

Rochester Fossils.

(Natural size.)

FIGURE 1. *Dictyonema retiforme* (Hall). Rochester shale. After Paleontology of New York, vol. II, pl. 40 F, fig. 1a. (Page 54.)

PLATE XI.

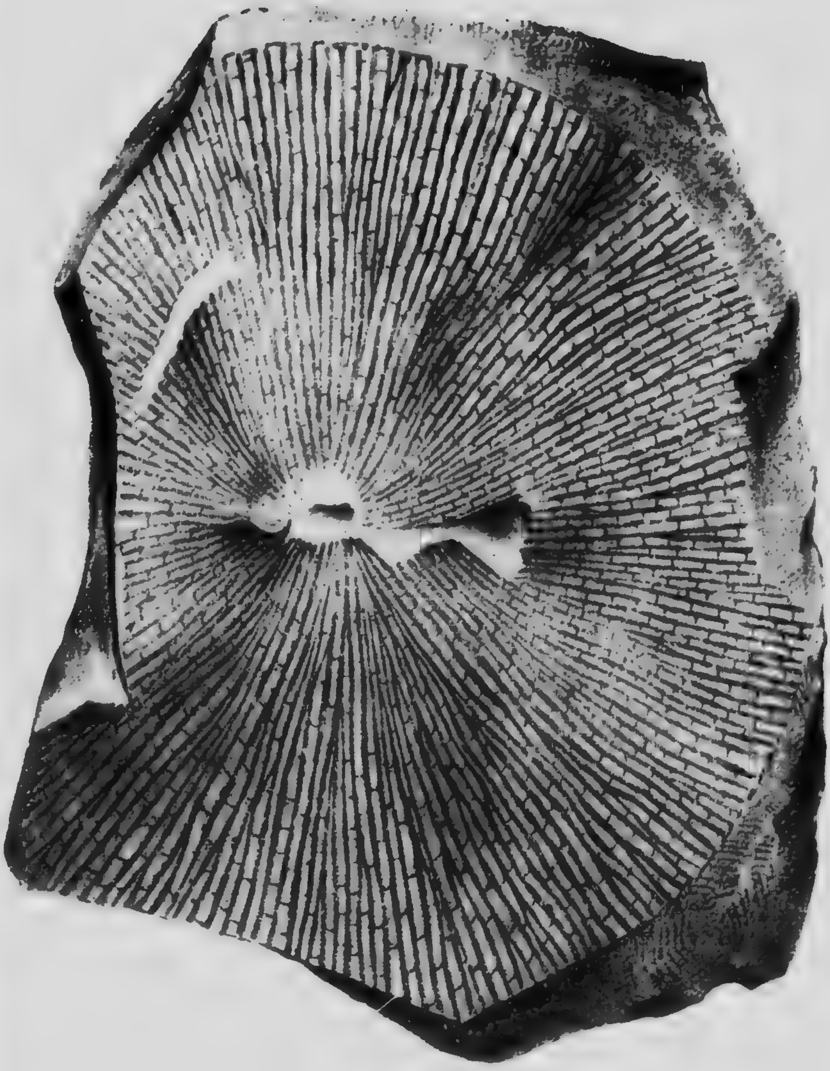


PLATE XII.

Rochester Fossils.

(Figures natural size except 10b.)

FIGURE 1. *Caryocrinites ornatus* Say. After Palæontology of New York, vol. II, pl. 49, fig. 1d. (Pages 54-56.)

FIGURE 2. *Stephanocrinus angulatus* Conrad. After Palæontology of New York, vol. II, pl. 48, fig. 1a. (Pages 54-56.)

FIGURE 3. *Spirifer cuspus* (Hisinger). 3a, 3b: two specimens from brachial side. After Palæontology of New York, vol. II, pl. 54, figs. 3c, 3d. (Pages 54-56.)

FIGURE 4. *Atrypa reticularis* (Linnaeus). 4a, pedicle valve, 4b, frontal view. After Palæontology of New York, vol. II, pl. 55, figs. 5n, 5o. (Pages 54-56.)

FIGURE 5. *Atrypa nodostriata* Hall. 5a, brachial, 5b, lateral, views. After Palæontology of New York, vol. II, pl. 5b, figs. 2m, 2n. (Pages 54-56.)

FIGURE 6. *Camarotœchia obtusiplicata* (Hall). 6a, brachial, 6b, pedicle, views. After Palæontology of New York, vol. II, pl. 58, figs. 2a, 2b. (Pages 54-56.)

FIGURE 7. *Rhipidomella hybrida* (Sowerby). 7a, pedicle, 7b, lateral views. After Palæontology of New York, vol. II, pl. 52, figs. 4f, 4g. (Pages 54-56.)

FIGURE 8. *Dalmanella elegantula* (Dalman). 8a, pedicle, 8b, frontal, views. After Palæontology of New York, vol. II, pl. 52, figs. 3c, 3h. (Pages 54-56.)

FIGURE 9. *Whitfieldella nitida oblata* (Hall). 9a, lateral, 9b, brachial, view. After Palæontology of New York, vol. II, pl. 55, figs. 2e, 2a. (Pages 54-56.)

FIGURE 10. *Bilobites acutilobus* (Ringueberg). 10a, pedicle valve, 10b, the same enlarged. After Proc. Acad. Nat. Sc., Phila., 1858, pl. VII, figs. 5 and 5a. (Pages 54-55.)

FIGURE 11. *Whitfieldella nitida* (Hall). 11a, lateral, 11b, brachial, views. After Palæontology of New York, vol. II, pl. 55, figs. 1n and 1o. (Pages 54-56.)

FIGURE 12. *Spirifer niagarensis* (Conrad), pedicle valve. After Palæontology of New York, vol. II, pl. 54, fig. 5k. (Pages 54-56.)

FIGURE 13. *Spirifer niagarensis* (Conrad). 13a, brachial valve, 13b, interior pedicle valve, showing crura (c). After Palæontology of New York, vol VIII, pt. II, pl. 21, figs. 1 and 2. (Pages 54-56.)

PLATE XII

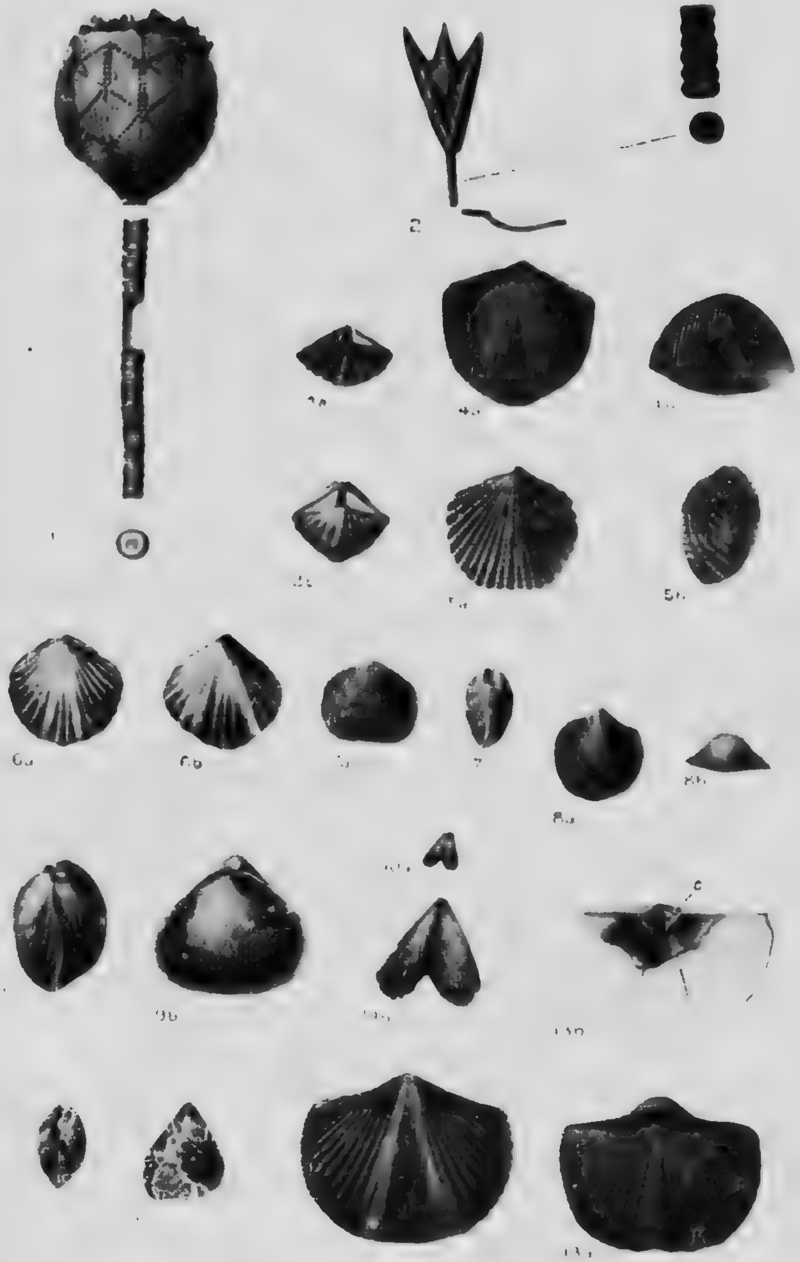


PLATE XIII.

Rochester Fossils.

(Figures natural size.)

FIGURE 1. *Strophonella? decewensis* n.sp. brachial valve. DeCew falls, Ont. G.S.C., Mus. No. 4687. (Page 124.)

FIGURE 2 a, b. *Schuchertella subplana* (Conrad), pedicle and cardinal views. From Palaeontology of New York, vol. II, pl. 53, figs. 10a, 10b. (Pages 54-56.)

FIGURE 3. *Platyceras angulatum* (Hall). After Palaeontology of New York, vol. II, pl. 60, fig. 1. (Pages 54-56.)

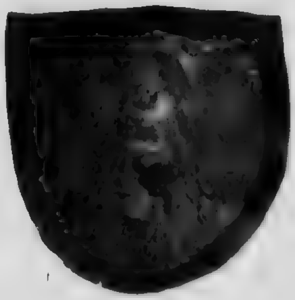
FIGURE 4. *Homalonotus delphinocephalus* (Green). After Palaeontology of New York, vol. II, pl. 68, fig. 4. (Pages 54-56.)

FIGURE 5. *Calymene niagarensis* Hall. After Chicago Academy of Sciences, Bull. IV, pl. 25, fig. 10. (Pages 54-56.)

FIGURE 6. *Diaphorostoma niagarense* (Hall). After Palaeontology of New York, vol. II, pl. 60, fig. 1. (Pages 54-56.)

FIGURE 7. *Diaphorostoma hemisphericum* (Hall). After Palaeontology of New York, vol. II, pl. 60, fig. 2a. (Pages 54-56.)

PLATE XIII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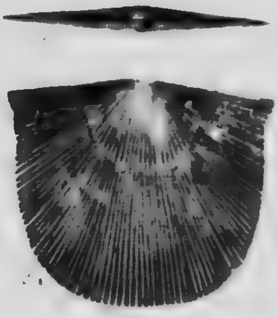
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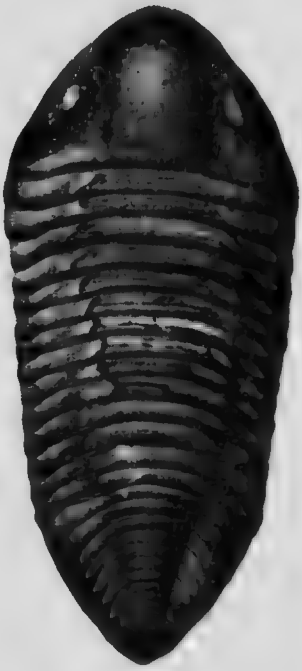
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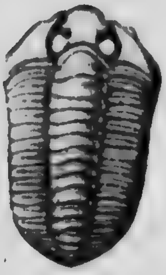
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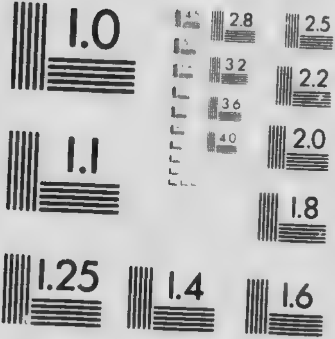


APPLIED IMAGE Inc

PLATE XIV.

Lockport Fossils.

(Figures natural size.)

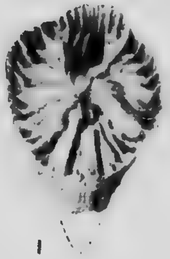
FIGURE 1. *Zaphrentis stokesi* Edwards and Haime. Above Fossil Hill horizon, New England, Manitoulin island. G.S.C., Mus. No. 4688. (Page 65.)

FIGURE 2. *Zaphrentis stokesi* Edwards and Haime. Boulder bluff, Cabot head, lake Huron. G.S.C., Mus. No. 4694. (Page 65.)

FIGURE 3. *Alveolites labechei* Edwards and Haime. Skunk island, south side Manitoulin island. G.S.C., Mus. No. 2642a. (Page 65.)

FIGURE 4. *Ptychophyllum stokesi* Edwards and Haime. Fossil hill, Manitoulin island. G.S.C., Mus. No. 4696. (Page 65.)

PLATE XIV.



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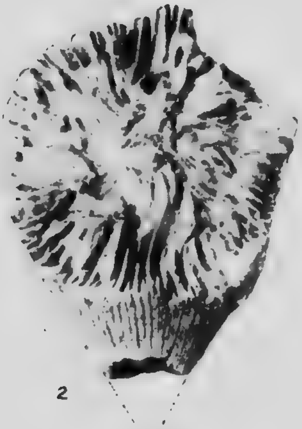

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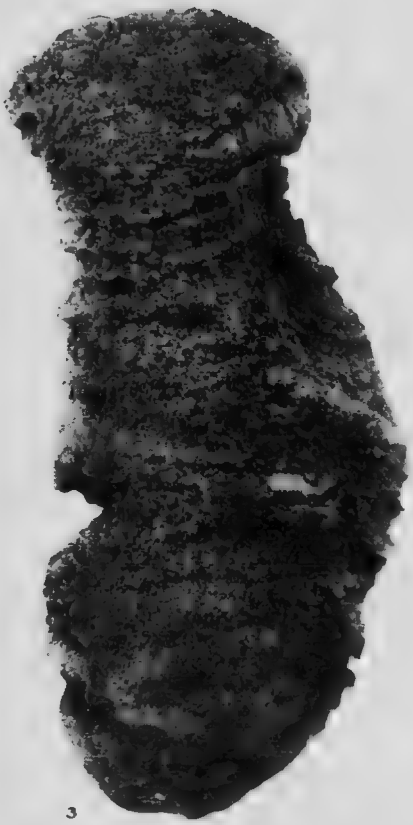

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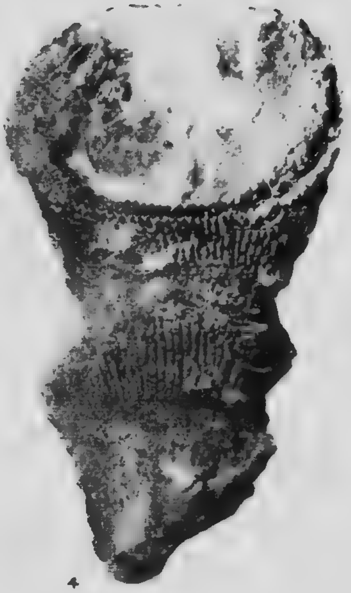

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Plate XV

Lockport Fossils.

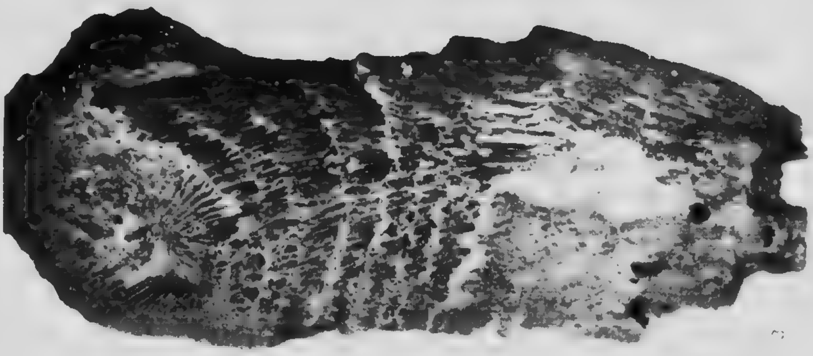
(Figures natural size.)

Figure 1. *Cyathophyllum solitarium* Billings' type. Portage bay, lake Manitou, Manitoulin island. G.S.C., Mus. No. 2637. (Page 65.

Figure 2. *Strombodes pentagonus* Goldfuss. Fossil hill. G.S.C., Mus. No. 5073. (Page 65.

Figure 3. *Ptychophyllum stokesi* Edwards and Haime. Fossil hill, Manitoulin island. G.S.C. Mus. No. 4696a. (Page 65.

PLATE XV.



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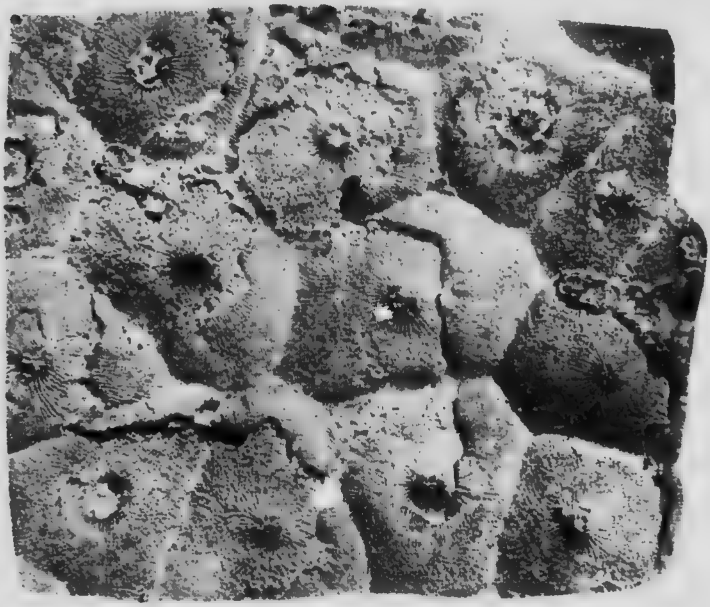

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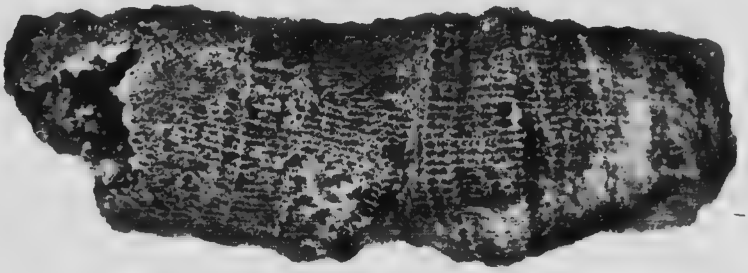

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PLATE XVI.

Lockport Fossils

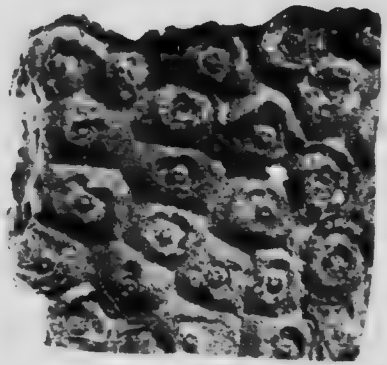
(Figures natural size.)

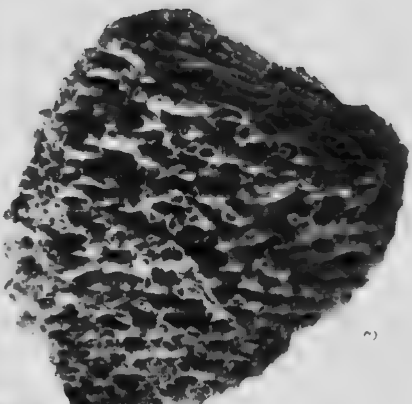
FIGURE 1. *Synaptophyllum multicaule* Hall. Fossil hill. G.S.C., Mus. No. 5074. (Page 65.

FIGURE 2. *Strombodes pentagonus* Goldfuss. Fossil hill. G.S.C., Mus. No. 5073a. (Page 65.

FIGURE 3. *Syringopora dalmani* Billings' type. Lake Timiskaming, collected by W. E. Logan G.S.C., Mus. No. 2618. (Page 65.)

PLATE XVI.





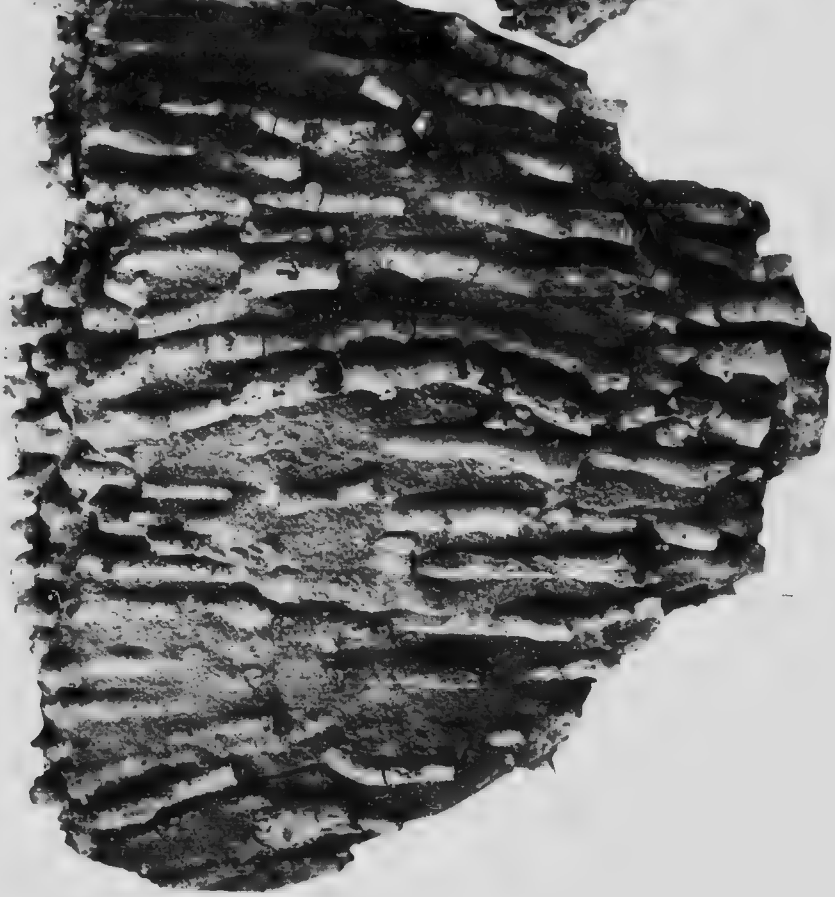


PLATE XVII.

Lockport Fossils.

(Figures natural size.)

FIGURE 1. *Syringopora retiformis* Billings' type. Owen Sound, collector R. Bell. G.S.C., Mus. No. 2617. (Page 65.)

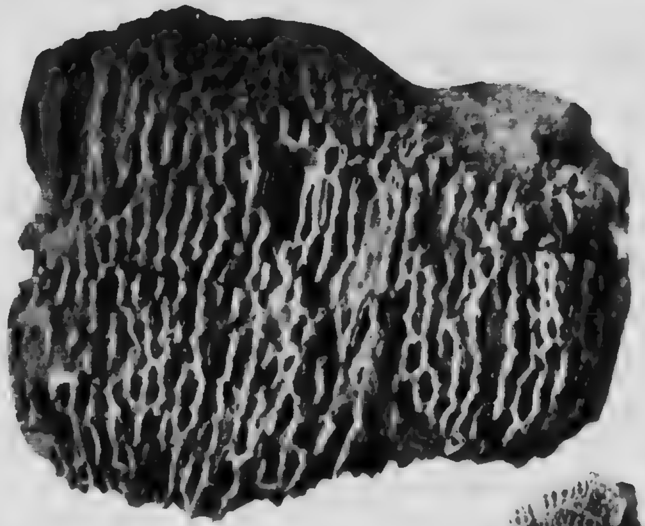
FIGURE 2. *Favosites hisingeri* Edwards and Haime. Fossil hill, Manitoulin island. G.S.C., Mus. No. 5075. (Page 65.

FIGURE 3. *Paleofavosites asper* D'Orbigny. Fossil hill, Manitoulin island. G.S.C., Mus. No. 5138. (Page 65.

FIGURE 4. *Syringopora fibrata* Rominger. Long bay, Manitoulin island, G.S.C., Mus. No. [illegible] Page 65

FIGURE 5. *Vermipora niagarensis* Rominger? Fossil hill, G.S.C., Mus. No. 5117. (Page 65

PLATE XVII.



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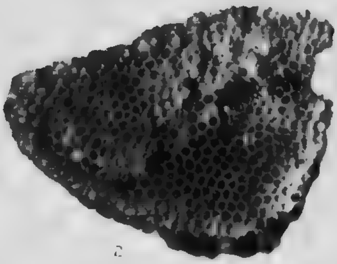

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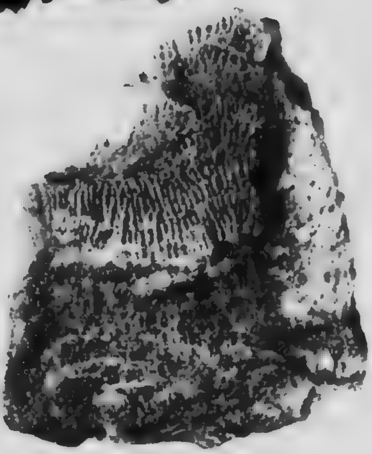

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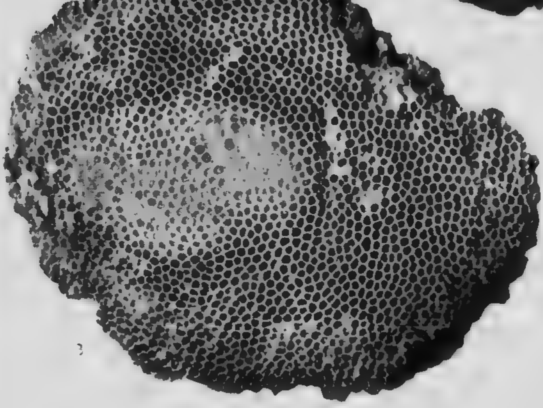

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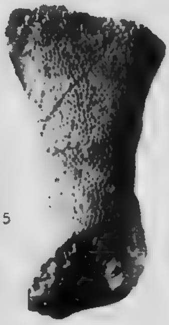

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PLATE XVIII.

Lockport Fossils.

(Figures natural size.)

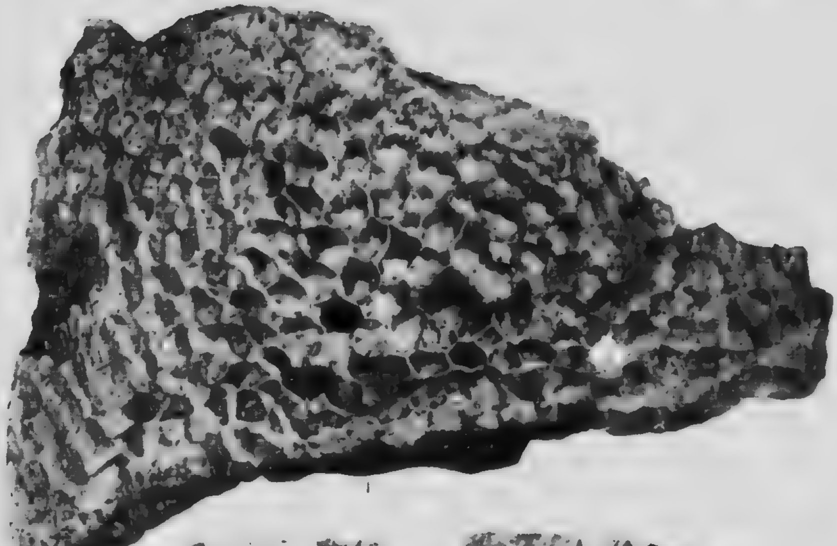
FIGURE 1. *Favosites favosus* (Goldfuss). Fossil hill, Manitoulin island, G.S.C., Mus. No. 5118. (Page 65.)

FIGURE 2. *Favosites hispidus* Rominger. Talus at Boulder bluff, Cabot head, lake Huron. G.S.C., Mus., No. 5119. (Page 65.)

FIGURE 3. *Cladopora reticulata* Hall. Plateau east of Sandfield, Manitoulin island. G.S.C., Mus. No. 5120. (Prge 65.)

FIGURE 4. *Lyellia americana* Edwards and Haime. Talus, Centre bluff, Cabot head, lake Huron. G.S.C., Mus. No. 5121. (Page 65.)

PLATE XVIII.



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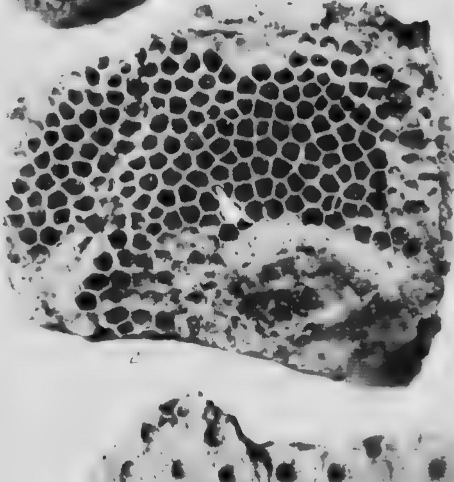

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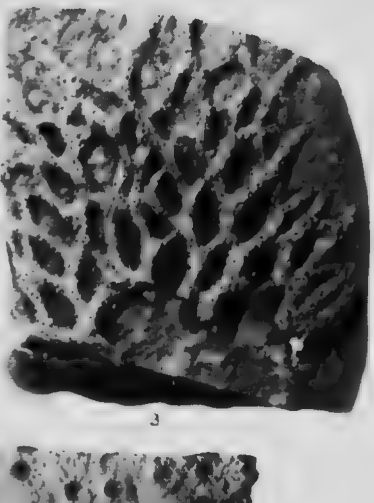

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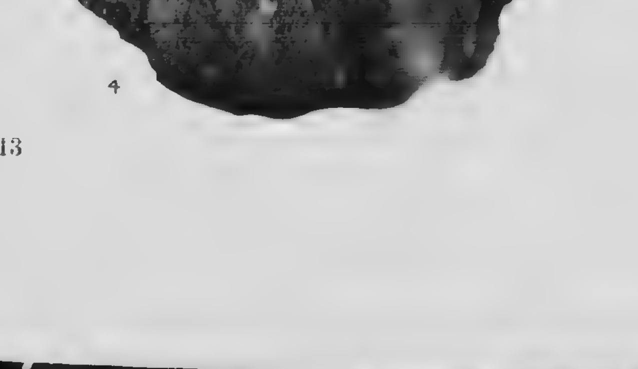

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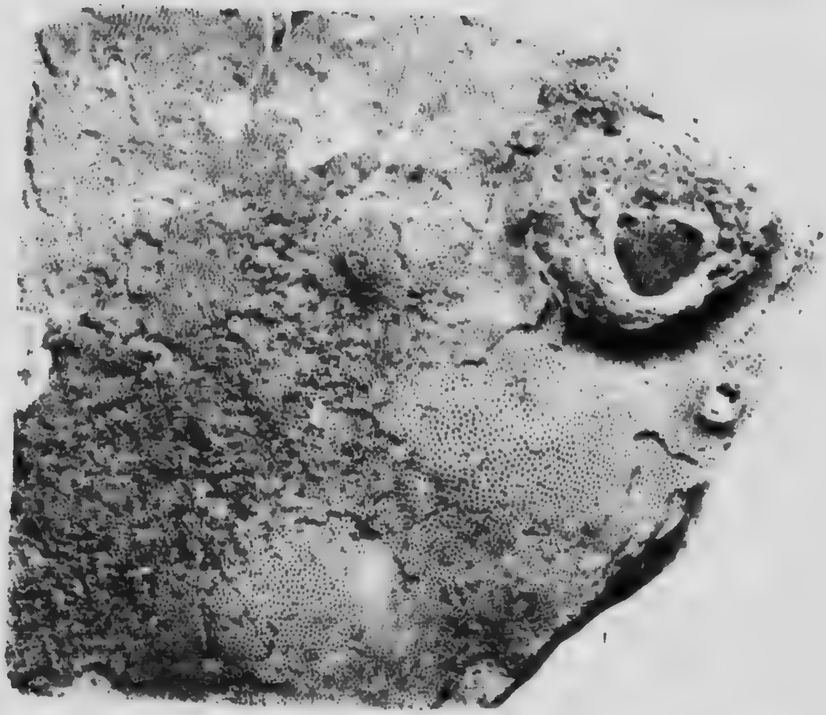
Plate XIX.

Lockport Fossils

Figures natural size

Figure 1. *Coenites crassus* (Rominger). Fossil hill, Manitoulin island. G.S.C., Mus. No. 51
Page 65.

Figure 2. *Halysites catenularia* (Linnaeus). Fossil hill, Manitoulin island. G.S.C., Mus. No. 5124. (Page 65.)



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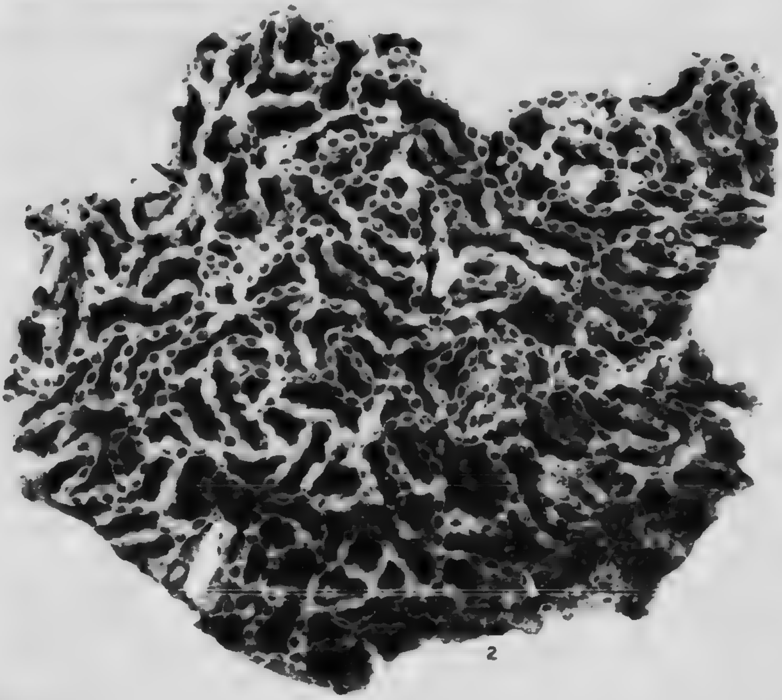

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PLATE XX.

Lockport Fossils.

(Figures natural size.)

FIGURE 1. ***Halysites catenularia microporus*** (Whitfield). Fossil hill, Manitoulin island. G.S.C., Mus. No. 5125. (Page 65.

FIGURE 2. ***Stricklandinia manitouensis*** n. sp. 2a, brachial, 2b, lateral, 2c, cardinal, views. Plateau east of Sandfield, Manitoulin island. G.S.C.,Mus. No. 5126. (Page 124.)

FIGURE 3. ***Stricklandinia manitouensis*** n. sp. Cardinal view of a comparatively thin specimen. G.S.C., Mus. No. 5126a. (Page 124.)

FIGURE 4. ***Homœospira apriniformis*** Hall. 4a, pedicle, 4b, frontal, views. Plateau east of Sandfield, Manitoulin island. G.S.C, Mus. No. 5127. (Page 67.)

FIGURE 5. ***Spirifer eudora*** (Hall). 5a, lateral view of a specimen from the Niagara group of Racine, Wisconsin; 5b, pedicle view of a specimen from the Niagara group of Waldron, Indiana. After Palæontology of New York, vol. VIII, pt. II, pl. 21, figs. 20, 21. (Page 67.)

FIGURE 6. ***Pentamerus oblongus*** Sowerby. Eight feet above base of Lockport dolomite at Wiarton. G.S.C., Mus. No. 5128. (Page 67.)

FIGURE 7. ***Clorinda ventricosa*** (Hall). 7a, brachial, 7b, lateral, views, of specimen from Niagara group of Waukeska, Wisconsin. After 20th Rept. New York Cabinet Natural History, pl. 13, figs. 18 and 19. (Page 67.)

PLATE XX.

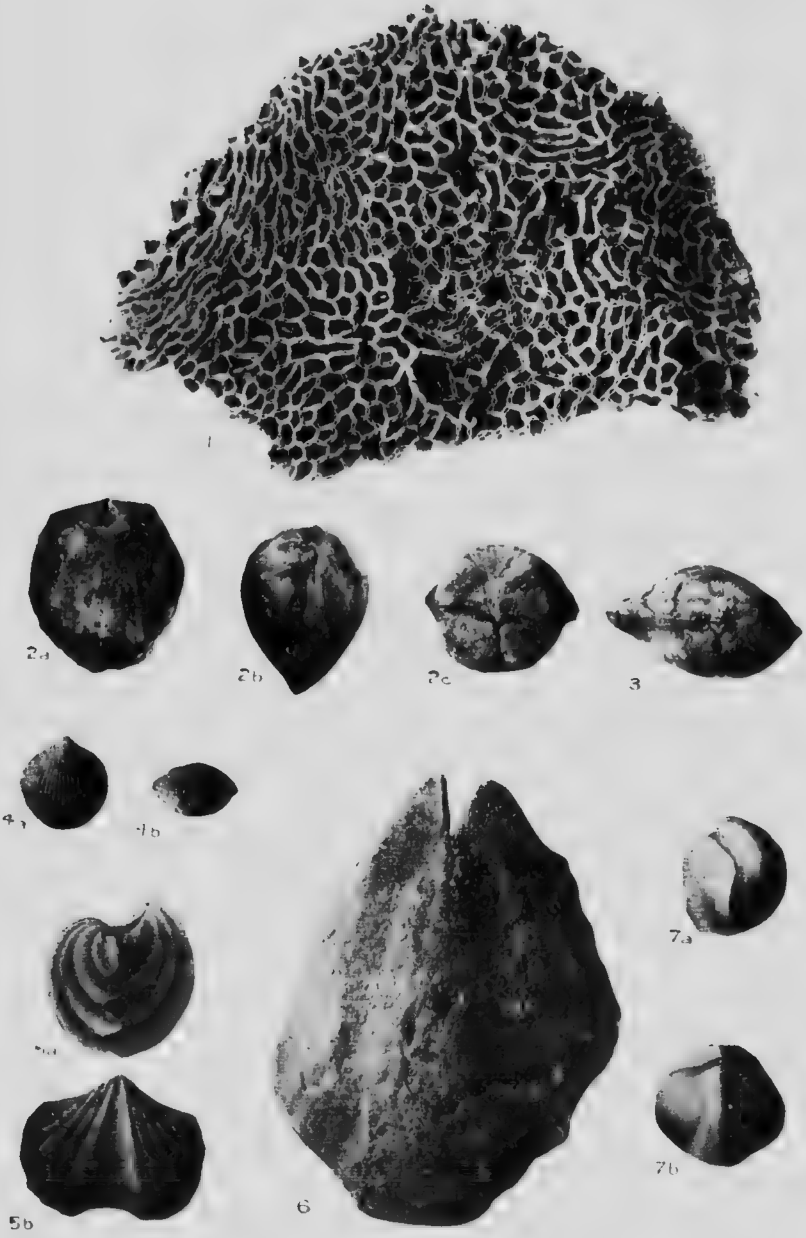


PLATE XXI.

Lockport Fossils.

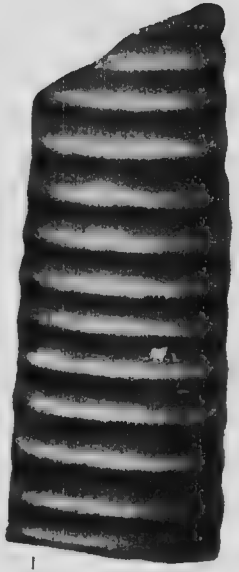
(Figures natural size.)

FIGURE 1. *Dawsonoceras annulatum* (Sowerby). After Palæontology of New York, vol. II, pl. 64, fig 1c. (Page 68.)

FIGURE 2. *Dalmanites limulurus* Green. West Flamboro, Ont. Collector, Foord, 1881. G.S.C., Mus. No. 2751. (Page 68.)

FIGURE 3. *Huronia vertebralis* Stokes. Huronia point, Cockburn island. Collector, R. Bell, 1866. G.S.C., Mus. No. 2733. (Page 68.)

Plate XXI.



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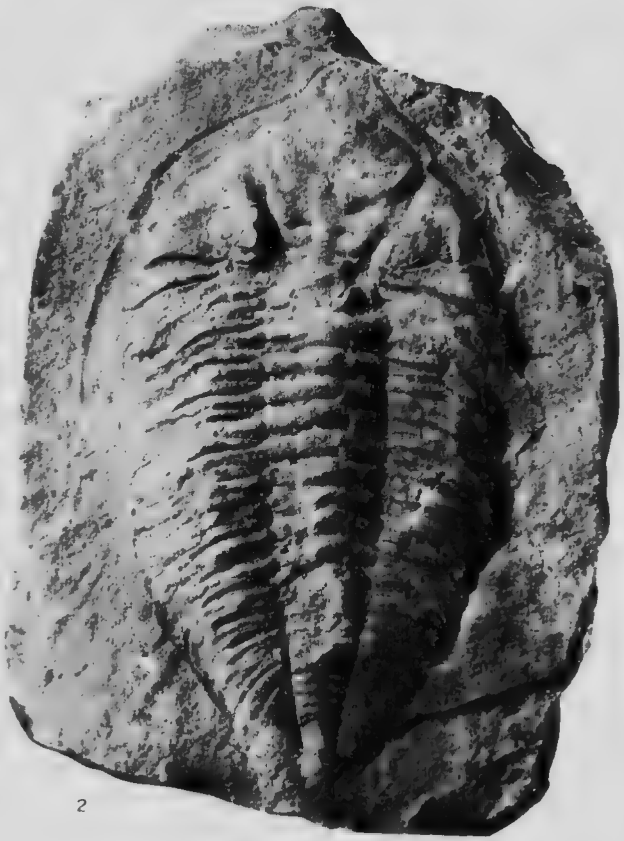

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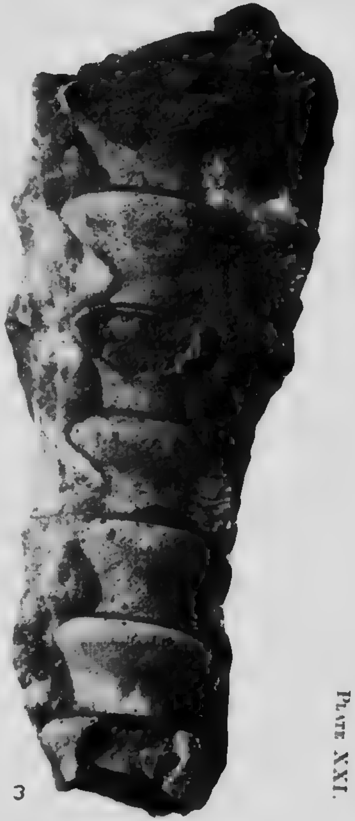

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PLATE XXII.

Guelph Fossils.

(Figures natural size.)

Figure 1. *Pycnostylus guelphensis* Whiteaves. Collected at Hespeler by E. Billings, 1857. G.S.C., Mus. No. 2789. (Page 77.)

Figure 2. *Pycnostylus elegans* Whiteaves type. Collected at Hespeler by T. C. Weston, 1867. G.S.C., Mus. No 2790c. (Page 77.)

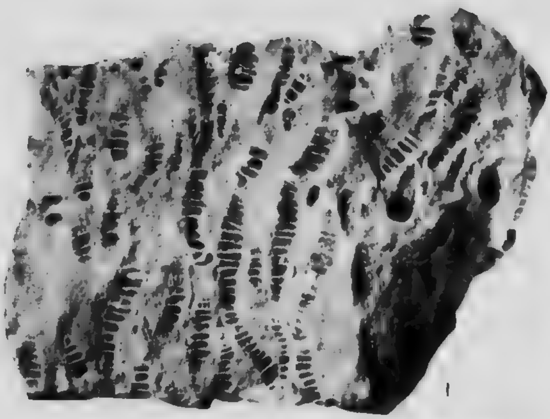
Figure 3. *Pycnostylus elegans* Whiteaves type. Interior view, showing tabulæ and marginal septa. Collected at Hespeler by T. C. Weston, 1867. G.S.C., Mus. No. 2790. (Page 77.)

Figure 4. *Trimerella grandis* Billings type. 4a, brachial, 4b, pedicle, views of an internal cast from Hespeler, Ont. G.S.C., Mus. No. 2803. (Page 77.)

Figure 5. *Whitfieldella hyale* (Billings). 5a, frontal, 5b, brachial, views. Hespeler, Ont. G.S.C., Mus. No. 2806. (Page 78.)

Figure 6. *Amphicœlia leidyi* Hall. From zinc prospect near Wiarton. G.S.C., Mus. No. 5129. (Page 78.)

PLATE XXII.



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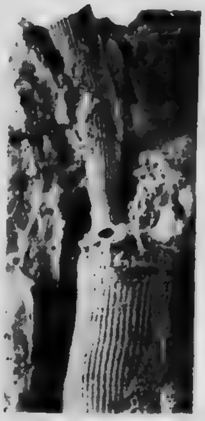

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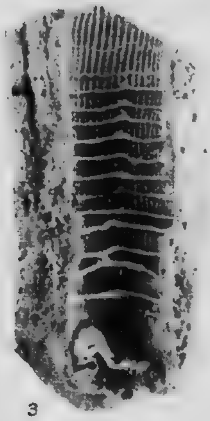

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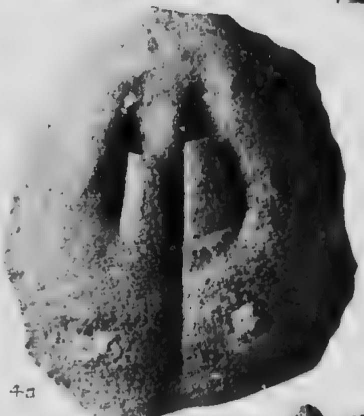
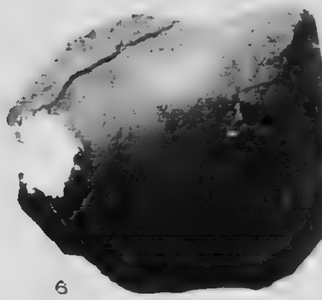


4a

5a

5b



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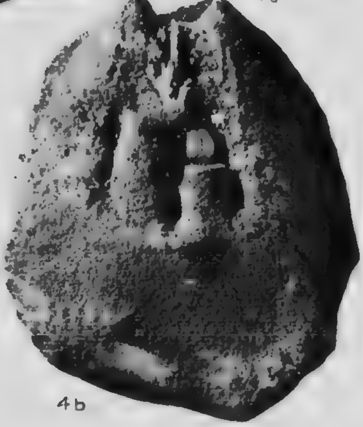


4b

PLATE XXIII.

Guelph Fossils.

(Figures natural size.)

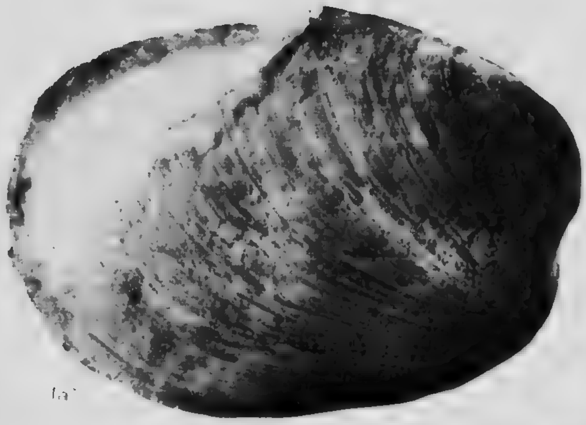
FIGURE 1. *Megalomus canadensis* Hall. 1a, right valve, 1b, dorsal view. Collected at Elora by D. Boyle, 1880. G.S.C. Mus. No. 2827. (Page 78.)

FIGURE 2. *Megalomus canadensis* Hall. Right side of internal cast. From Galt, Ont. G.S.C. Mus. No. 5130. (Page 78.)

FIGURE 3. *Conchidium occidentalis* (Hall). 3a, cardinal area of cast of interior; 3b, brachial valve. After Geology of Canada. 1863, p. 337, fig. 341, a and c. (Page 77.)

FIGURE 4. *Mytilarca acutirostra* (Hall). Cast of interior. After 20th Rept. Cabinet of Natural History, New York State, pl. 14, fig. 2. (Page 78.)

PLATE XXIII.



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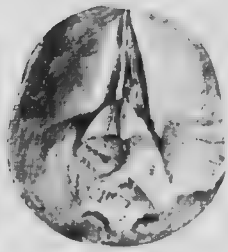

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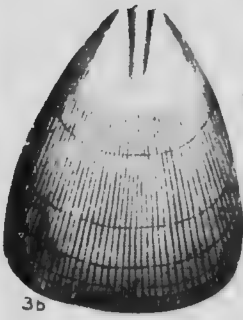

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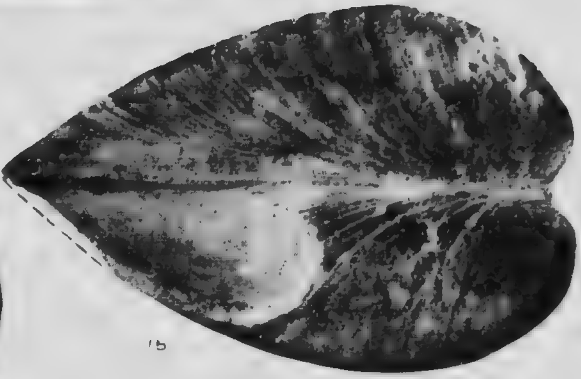

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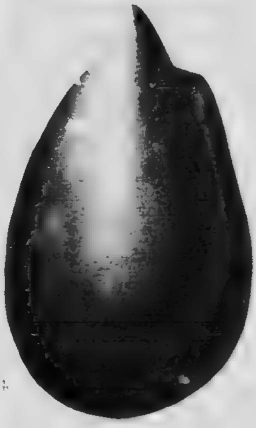

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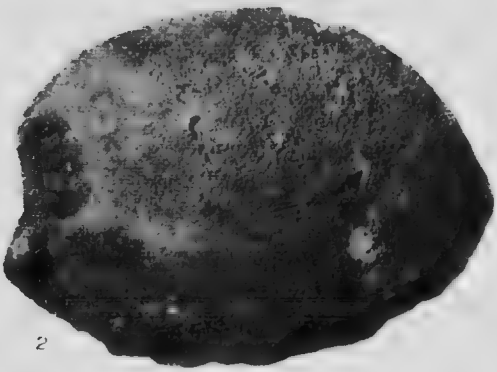

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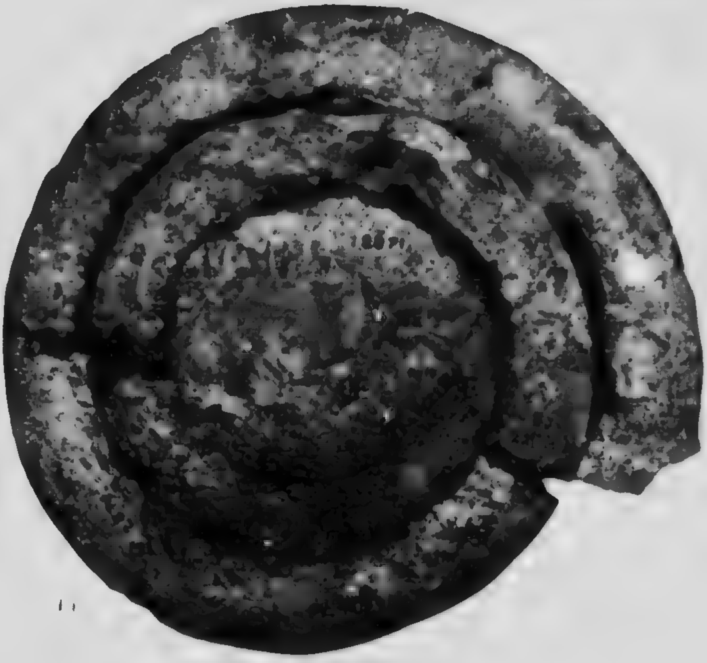
PLATE XXIV.

Guelph Fossils.

(Figures natural size.)

FIGURE 1. *Liospira perlata* (Hall). 1a, top, and 1b, basal, views. From Galt, Ont. G.S.C. Mus. No. 2871. (Page 78.)

PLATE XXIV.



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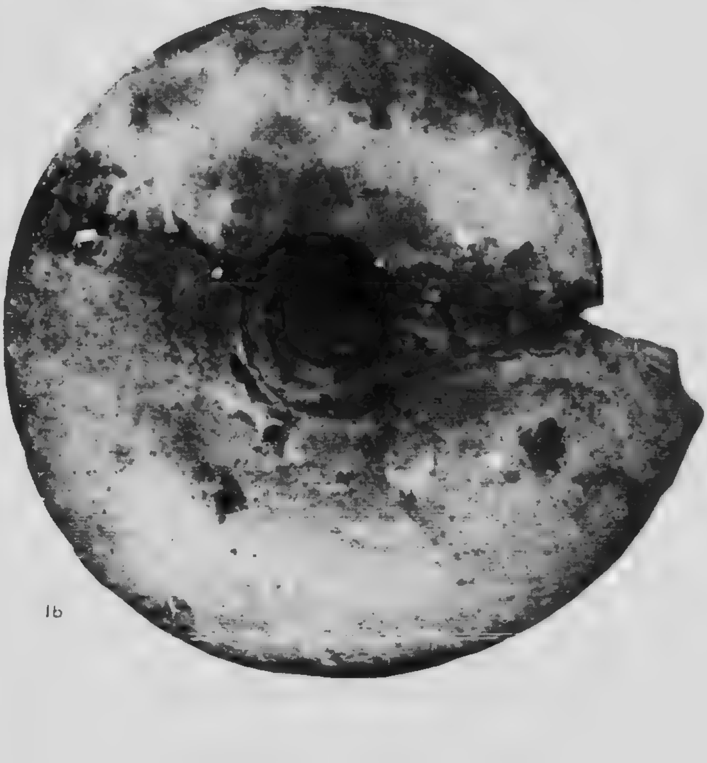


1b

PLATE XXV.

Guelph Fossils.

(Figures natural size.)

FIGURE 1. *Cœlocaulus longispira* (Hall). Natural section showing interior. From Baptist harbour, Bruce peninsula. G.S.C., Mus. No. 5131. (Page 78.)

FIGURE 2. *Cœlocaulus longispira* (Hall). Small specimen collected at Denham by J. Townsend, 1874-82. G.S.C., Mus. No. 2895a. (Page 78.)

FIGURE 3. *Hormotoma cf whiteavesi* Clarke and Ruedemann. This specimen is more slender than those described by Clarke and Ruedemann. Collected at Elora or Hespeler by T. C. Weston, 186 . G.S.C., Mus. No. 2859b. (Page 81.)

FIGURE 4. *Cœlocaulus vitellia* (Billings). Collected at Galt by E. Billings, 1857. G.S.C., Mus. No. 2882. (Page 81.)

FIGURE 5. *Straparollina daphne* (Billings), umbilical view. Collected at Elora by D. Boyle, 18 G.S.C., Mus. No. 2856. (Page 81.)

FIGURE 6. *Holopea guelphensis* Billings. Collected at Durham by A. Murray, 1857. G.S.C. Mus. No. 2848. (Page 79.)

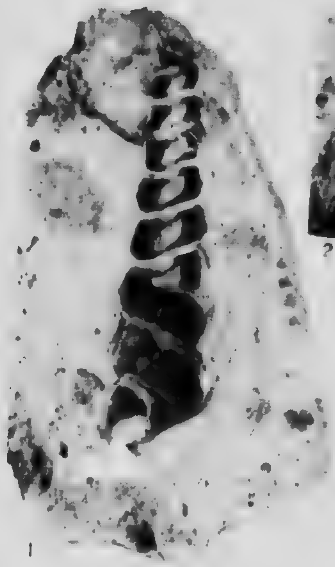
FIGURE 7. *Euomphalus galtensis* Whiteaves. Collected at Durham by J. Townsend. G.S.C., Mus. No. 2853. (Page 78.)

FIGURE 8. *Murchisonia billingsana* Miller. Collected at Galt? by T. C. Weston, 1857. G.S.C., Mus. No. 2875. (Page 81.)

FIGURE 9. *Cœlocaulus vitellia* (Billings). Collected at Durham by J. Townsend, 1882. G.S.C., Mus. No. 2881. (Page 81.)

FIGURE 10. *Tremanotus angustatus* (Hall). Collected at Hespeler by E. Billings and A. Murr , 1867. G.S.C., Mus. No. 2911a. (Page 80.)

PLATE XX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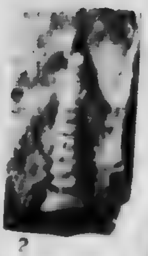
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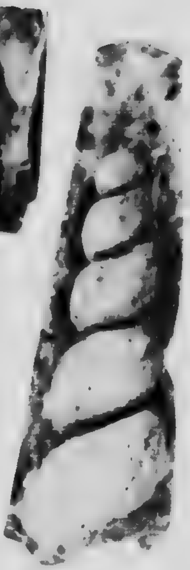
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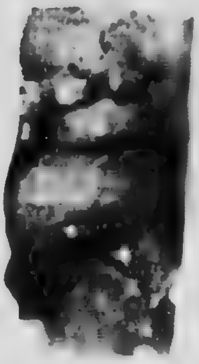

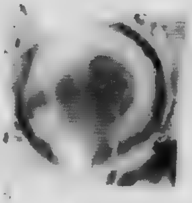

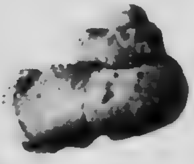
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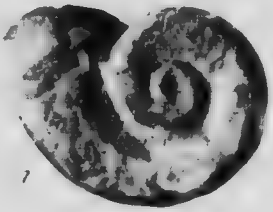
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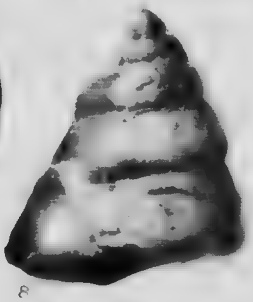
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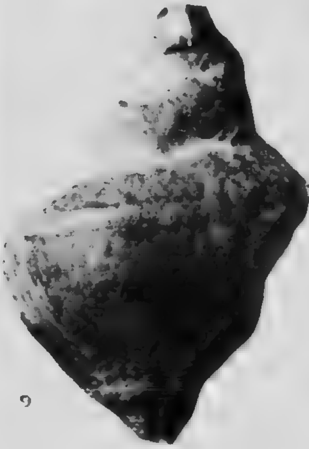
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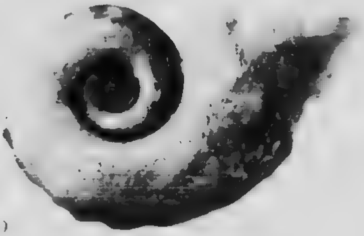
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PLATE XXVI.

Guelph Fossils.

(Figures natural size.)

FIGURE 1a. *Orthoceras brucensis* n. sp. Partly natural and partly artificial longitudinal section. From Hay bay, Bruce peninsula, Ont. G.S.C., Mus. No. 5732. (Page 124.)

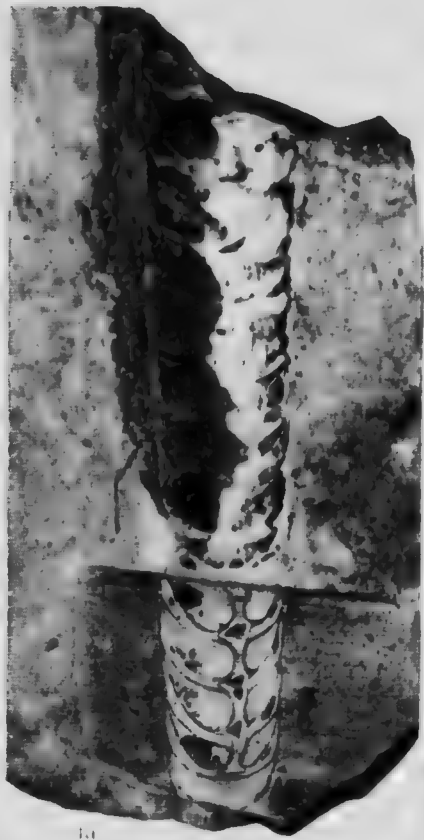
FIGURE 1b. Smallest camera showing position of siphuncle. (Page 124.)

FIGURE 2. *Poterioceras* n. sp., septum next to living chamber showing location of siphuncle. From lower Guelph at zinc prospect near Wiarton. G.S.C., Mus. No. 5133. (Page 79.)

FIGURE 3. *Poterioceras* n. sp., segment near distal end. G.S.C., Mus. No. 5133a. (Page 79.)

FIGURE 4. *Poterioceras* n. sp., much of living chamber and the greater part of the body. Locality same as Figures 2 and 3. G.S.C., Mus. No. 5134. (Page 79.)

PLATE XXVI



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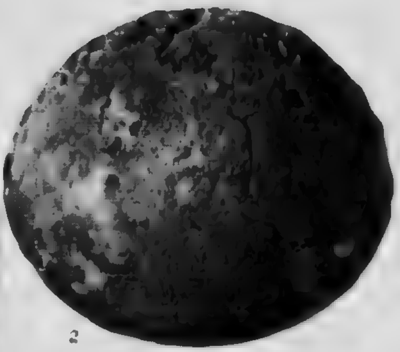

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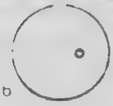

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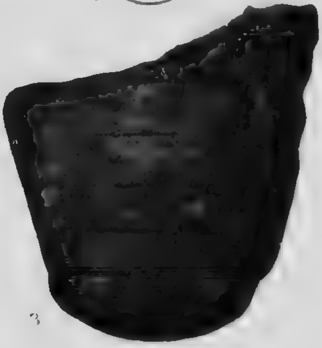

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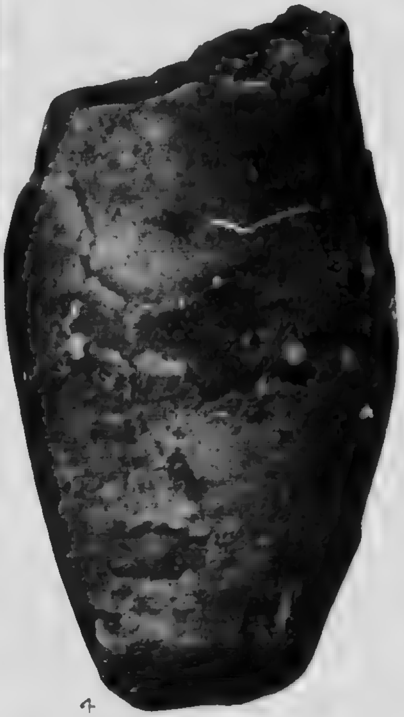

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PLATE XXVII.

Guelph and Cayugan Fossils.

(Figures natural size except 4 and 5.)

Guelph.

FIGURE 1. *Orthoceras brucensis* n. sp., showing external characters of shell. From Pine Tree harbour, Bruce peninsula, Ont. G.S.C., Mus. No. 5135. (Page 124.)

FIGURE 2. *Mælonoceras arcticameratum* (Hall). From cape Hurd, Bruce peninsula, Ont. G.S.C., Mus. No. 5136. (Page 79.)

Cayugan.

FIGURE 3. *Eurypterus remipes* Dekay. From top of Bertie waterlime. After New York State Mus. Mem. 14, pt. 2, pl. 5, fig. 5. (Page 83.)

FIGURE 4. *Whitfieldella sulcata* (Vanuxem) magnified 2 diameters; pedicle valve. Akron dolomite one-quarter mile west of Ridgemount, Welland county. G.S.C., Mus. No. 5137. (Page 86.)

FIGURE 5. *Whitfieldella sulcata* (Vanuxem) magnified 2 diameters; frontal view showing sinus on both valves, the upper being the pedicle. G.S.C., Mus. No. 5137a. (Page 86.)

PLATE XXVII.

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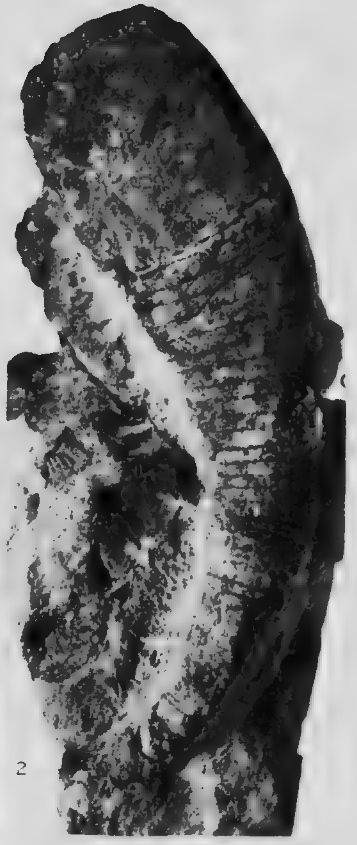
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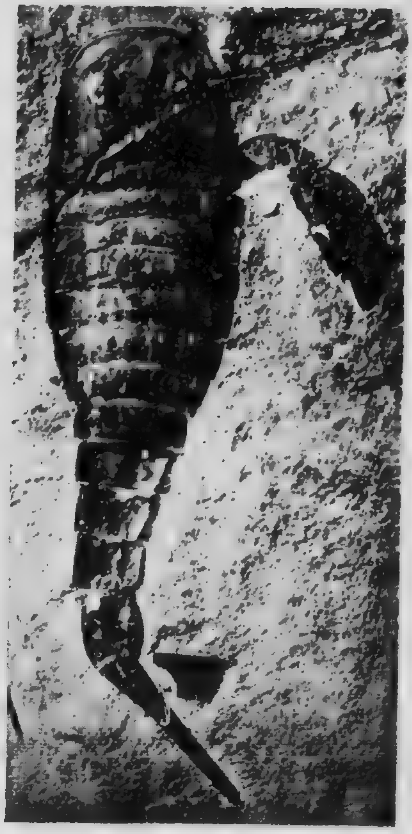
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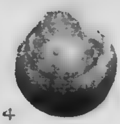
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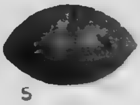
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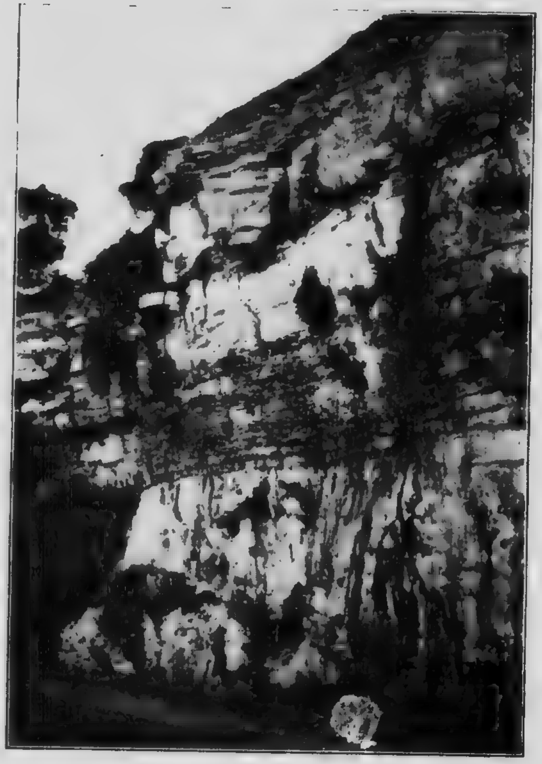
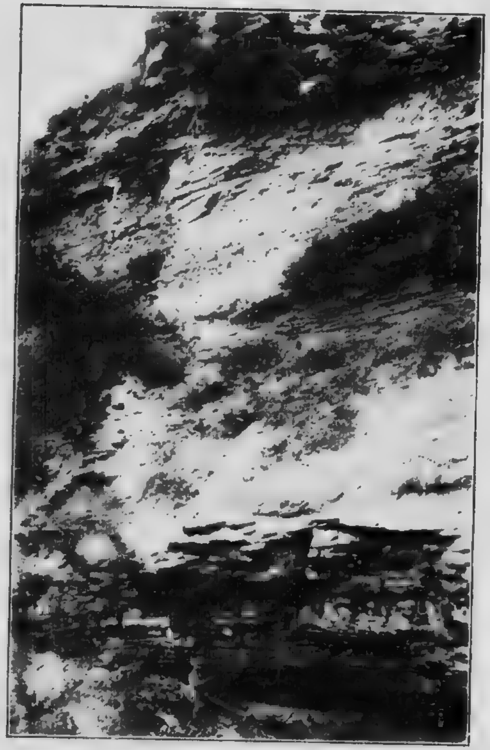
PLATE XXVIII.



A. Lockport and Guelph dolomite. Thin beds 12 feet thick near centre are Eramosa beds. Below car barn, Gorge route, Niagara falls, New York. (Pages 62 and 73.)

B. Medina sand-stone and shale, from Manitoulin beds at bottom to Clinton dolomite at top of hill. Thorold sand-stone is conspicuous bed near top. New York Central and Hudson River railway above Lewiston, New York. (Page 24.)



A. Section of Clinton dolomite, Rochester shale, and lower part of Lockport dolomite, at Grimsby. (Pages 46 and 52.)

B. Section of Cabot Head shale. Grimsby sandstone and Reynales dolomite (at very top), at falls on Twentymile creek, south of Jordan. (Pages 32 and 39.)

PLATE XXX.

A. Section of DeCew waterlime (a little more than the lower half of the picture) and the Gasport and overlying Lockport dolomite. Niagara gorge, New York. (Page 58.)

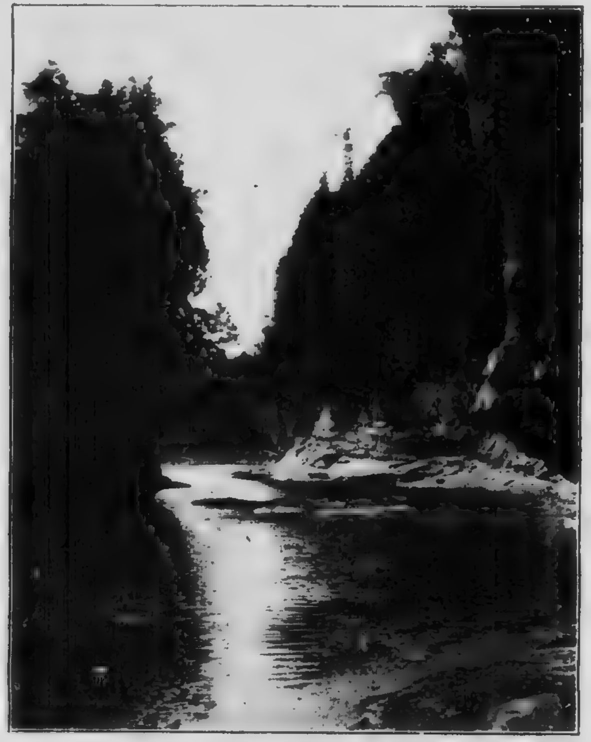
B. Section of upper Cabot Head shale showing current channel. Niagara gorge, New York. (Page 34.)

PLATE XXXI.

A. [illegible] Bay dolomite and underlying red Cabot Head shale, at a locality 3 miles west of Cabot head. (Page 33.)

B. Quarry in Manitoulin dolomite, Owen Sound. (Page 28.)

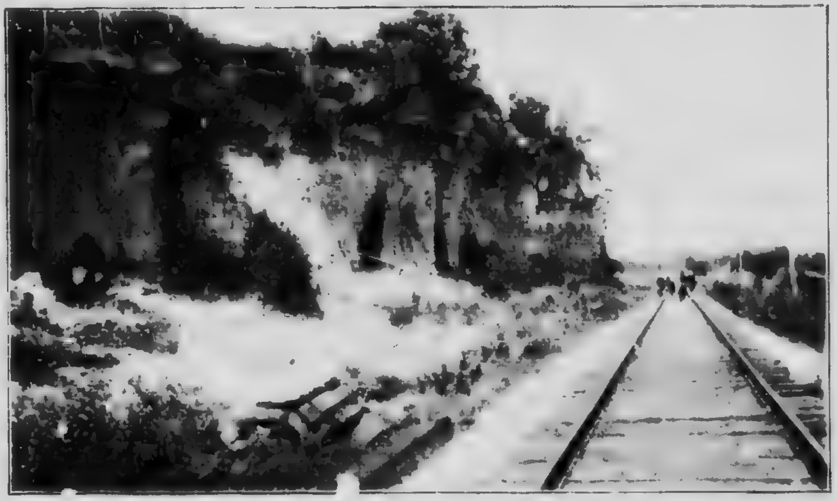
PLATE XXXII.



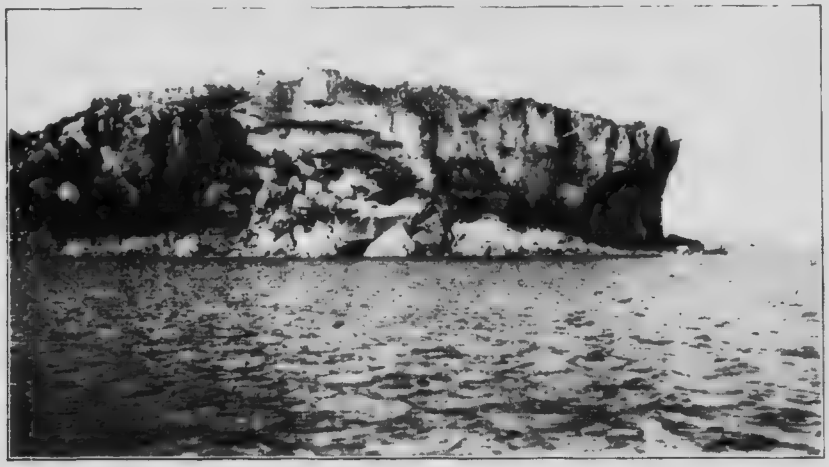
A. Gorge of Grand river, in Guelph dolomite near Elora. (Page 72.)

B. Niagara escarpment. Cliffs of Lockport dolomite near Kolapore, Grey county. (Page 57.)

PLATE XXXIII.



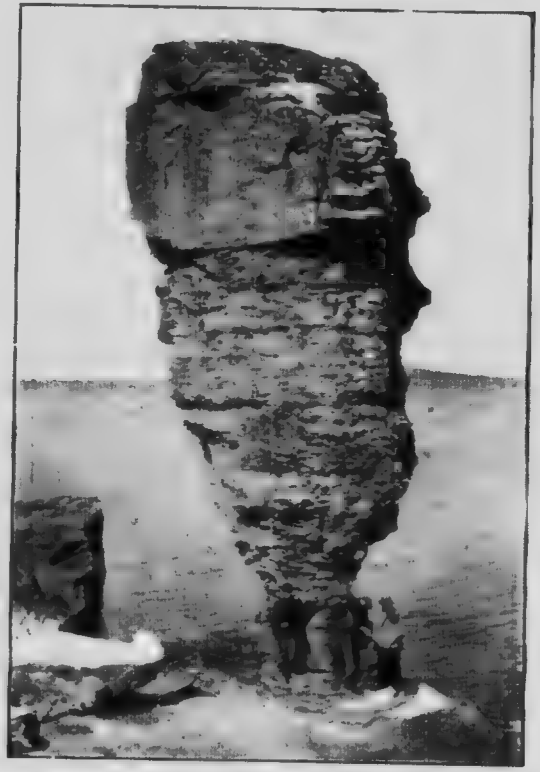
A. Eramosa beds and base of Guelph dolomite, near Guelph. (Page 62.



B. Upper Lockport and lower Guelph dolomite (caves below contact), Half-way rock, north end Bruce peninsula. (Page 62.)

PLATE XXXIV.

A. Shelburne post-office, made from local Lockport dolomite. (Page 97.)



B. Larger Flower pot, composed of Eramosa dolomite, capped with Guelph dolomite. Flowerpot island, Georgian bay. (Page 62.)

INDEX.

A.

PAGE.
Acknowledgments 2
Age, Medina-Cataract formation 42
Akron dolomite 16
" (dolomite) formation 87
" " fossils 89
" fossils 87
Alabastine Company 8, 104
Alexandrian series, fossils 43
Analyses, Bertie waterlime 116
" brine from rock salt, southwestern Ontario 106
" " Delray Salt Co., Delray, Michigan 107
" " New York state 107
" " Platt well, Goderich 106
" Camillus shale 115
" Clinton formation 111
" DeCew waterlime beds, Lockport dolomite 112
" Guelph dolomite 114
" Irondequoit dolomite 111
" Lockport dolomite 113
" Manitoulin dolomite 110
" Reynales (Wolcott) dolomite 111
" Rochester shales 111
" rock, Ancaster quarries 114
" " salt, Attrill well, Goderich 107
" " " New York state 108
Anticlines 12
Anticosti section 45
Atrypa parski, new species 120

B.

Barton beds 61
Bass Island 22
" (Lower Monroe) formations 99
" series 89
" " fossils 90
Bassler, R. S. 2
Bell, R. 3
Bertie-Akron formation 116
Bertie waterlime formation 84, 100
" fossils 86
" origin 86
" (Williamsville) waterlime fossils 86
Bibliography 4
Big Chicken island 91
Bourne, G. B. 102
Brachiopod, new species of 126
Brick 102
Building stone 16, 96
Butts, C. 57
Byng 88

C.

Cabot Head lighthouse .... PAGE.
Cabot Head member, origin 32
" shale, fossils 38
" " member 35
Caledonia gypsum mine 32
Cambrian 115
Camillus shale member 9
" origin 83
Canada Crushed Stone Corporation, Ltd 84
Canadian Pacific railway 99, 101, 114
" Salt Company 80
Carson mine 106
Cataract and Brassfield formation compared 104
" formation 45
Cayugan group 23, 24
" " correlation 11, 82
" history 94
Cement 94
Chadwick, G. H. 100
Chamberlain, T. C. 2, 85, 93, 128
Chemicals 75
Chert nodules 101
Cincinnati anticline 60
Clapp, F. G. 12
Clarke, Mr. 4, 96
Clay cliffs 3
Clinton formation 33
Clinton limestone 11, 46
" member, correlation 16
Cole, L. H. 52
Conclusions 4, 96
Coral, new species of 15
Correlation, Bertie and Akron formations with Bass Island series 128
" Cayugan group 93
" Clinton members 94
" Guelph formation 52
" Medina-Cataract formation 75
" Niagara group 42
Credit Forks 69
" Valley 25
" " sandstone 97
Crinoid, new species of 96
Crowell, Mr. 127
Crown Gypsum Company 114
Crushed stone 104
99

D.

Dalmanella eugeniensis new species
" " var palæoelegantula Williams n. var. 118
DeCew waterlime 118
" beds 70
" fossils 100
" member 58
Detroit River 58
" fossils 22
Devonian 19
Disconformities 9
Dolomite for flux 15
" lime manufacture 101
Dolomites 101
Doolittle, Mr. 16, 97
Dowling, D. B. 114
75

PAGE.
Drill core 83, 85
Dyer Bay dolomite 34
" " and Edgewood limestone compared 44
" " fossils 35, 37
" " lentille 35

E.

East Sister island 91
Ellsworth, H. V 2, 110, 123
Eramosa beds 12, 60, 99
" member 62
" fossils 62
Eucheirocrinus Ontario new species 127

F.

Falkirk, fossils 85
Flowerpot island 62
Flowerpots 62
Flux, dolomite for 101
Foerste, A. F 126
Folds 12
Fossil Hill coral horizon 61
Fossils 69
" Akron 87
" " dolomite 89
" Alexandrian series 43
" Bass Island series 90
" Bertie waterlime 86
" Cabot Head shale 35
" DeCew waterlime 58
" Detroit River 19
" Dyer Bay dolomite 35, 37
" Eramosa 62
" Falkirk 85
" Gasport dolomite 60
" Greenfield dolomite 90
" Grimsby sandstone 40
" Guelph 71, 77
" " formation, revised list 80
" Lockport 64
" Manitoulin dolomite 30
" " member 29
" Middle Sister island 92
" Niagara River Furnaceville (Sodus) shale 48
" Ontario, Irondequoit 51
Fossils, Ontario, Reynales (Wolcott) 49
" " Rochester 54
" St. Edmund dolomite 37
" Thorold sandstone 41
" Whirlpool sandstone 26, 28
Furnaceville (Sodus) shale, fossils, Niagara River 48
" " member 47

G.

Galt section 72
Gas 8, 109
Gasport dolomite fossils 60
" " member 59
Geology, economic 16, 96
" general 9, 15
" southwestern Ontario 8
Glacial striæ 91, 92
Goldthwait, J. W 11
Grabau, A. W 3, 84

PAGE
Greenfield dolomite 90
" " fossils 90
Grey band 41
Grimsby sandstone fossils 40
" " member 39
" " microscopic characters 40
" " origin of 40
Guelph dolomite 11, 16
Guelph formation 70, 124
" correlation 75
" fossils 71, 77
" " revised list 80
" sedimentation 76
Gypsum 8, 16, 83, 103

H.

Hall, J 3
Hen island 91
Hume, G. S 2, 30, 44
Hunt, T. Sterry 3

I.

Innerkip 88
Iron band 36
Irondequoit dolomite member 50
fossils, Ontario 51

K.

Keele, J 102
Kindle, E. M 2, 44, 59
Knight, C. W 4, 96

L.

Lake Superior Corporation, Quarry point 98
Lime manufacture, dolomite for 101
Lingula cuneata Hall 117
Little Chicken island 91
Lockport dolomite formation 11, 16, 57, 62
Lockport dolomite, undivided 60
" formation 124
" fossils 64
Logan, Sir W 3
Lophospira pulchra new species 123
Lucas island 74

M.

Magnesian limestone 97
Malcolm, W 4, 96
Manitoulin dolomite and Brassfield limestone compared 44
" " fossils 30
" member 28
" " microscopic character 29
" " origin 29
Manitowaning 97
Martindale mine 105
Medina-Cataract formation 11, 23, 110, 117
" " correlation and age 42
" formation 23
" sandstone 16, 96

PAGE

Michigan Central railway 88
Middle Sister island 92
" " fossils 92
Modiolopsis kelsoensis new species 123
Monroe formation, age 21
" " erosion 20
Monroe formation, table of succession 18
Municipal quarry 85
" road-metal quarry 88
Murray, A 2
Murray, Mr 114

N.

Nattress, T 18
New York Central and Hudson River railway 48
Niagara escarpment 8
" group 11, 52, 111
" " correlation 69
" limestone 57
" sedimentation 70
Nicholson, H. A 3
Nigger Head bed 50
North Harbour island 92
Nuculites (Cleidophorus) cf ferrugineum Foerste 121

O.

O'Connell, Miss 86
Oil 16
Ontario Gypsum Co., Ltd 8, 104
Orangeville 97
Ordovician 9
Orthoceras brucensis new species 124
Owen Sound 97

P.

Palæontology 117
Palæophyllum (Cyathophylloides?) Williamsi sp. nov 128
" umbellicrescens sp. nov 129
Palæozoic 9
Parks, W. A 3, 4, 96, 121
Pentamerus oblongus 61
Petroleum 108
Platt, Mr 106
Plucky island 74
Poitevin, E 63
Portland cement 101
Previous work 2
Pterinea brisa Hall? 122
" cf undata (Hall) 122
Put-in-Bay dolomite 90

Q.

Quarries 97, 99, 100

R.

Raisin River dolomite 90
Reinecke, L 96, 99
Reynales dolomite, guide fossils 48
" (Wolcott) dolomite member 48
" " fossils, Ontario 49

PAGE.
Rhynchotreta cabotensis new species 120
" **Williamsi new species** 126
Road metal 16, 99
Rochester formation 11, 124
" **fossils, Ontario** 54
" **shale formation** 53
Rock analysis 110
Rogers brothers 2
Ruedemann, R. 3
Ryan and Haney's quarry 113

S.

St. Edmund dolomite 34
" " **fossils** 37
" " **lentille** 37
Salem-Elora section 71
Salina dolomite 16
" **formation** 16, 82, 115
Salt 8, 16, 83, 105
Schuchert, C. 2, 3
Section, Akron dolomite 88
" **Bass Island series** 91
" **Bertie waterlime** 85
" **Camillus shale** 83
" **Dyer Bay dolomite** 36
" **Eramosa beds** 62
" **Gasport dolomite** 59
Section, Guelph formation 71
" **Manitoulin dolomite** 34
Shale 102
Sherzer, W. H 3
Silurian 9, 15
" **system, boundaries and subdivisions** 17
" " **extent and boundaries** 17
Springer, Frank 127
Springvale 88
Standard White Lime Company 101
" " **quarry** 72
Stansfield, J 2, 119, 123
Stauffer, C. R 1, 3
Stricklandinia manitouensis new species 124
Strophonella decewensis new species 124
Structure 11
Summary 15
Sylvania sandstone overlap 20

T.

Table of formations 93
Taylor, F. B 11
Thorold quartzite 41
" **sandstone fossils** 41
" " **member** 41
" " **microscopic character** 41
" " **origin** 42
Tile 102
Tonawanda Gas Company 14
Topography 8
Townsend, J. 73
Twenhofel, W. H. 69
Tymochtee shales 90

U.

Ulrich, E. O 2, 17

V.

PAGE.
Virgiana Mayvillensis and Pentamerus Oblongus, measurements of 119

W.

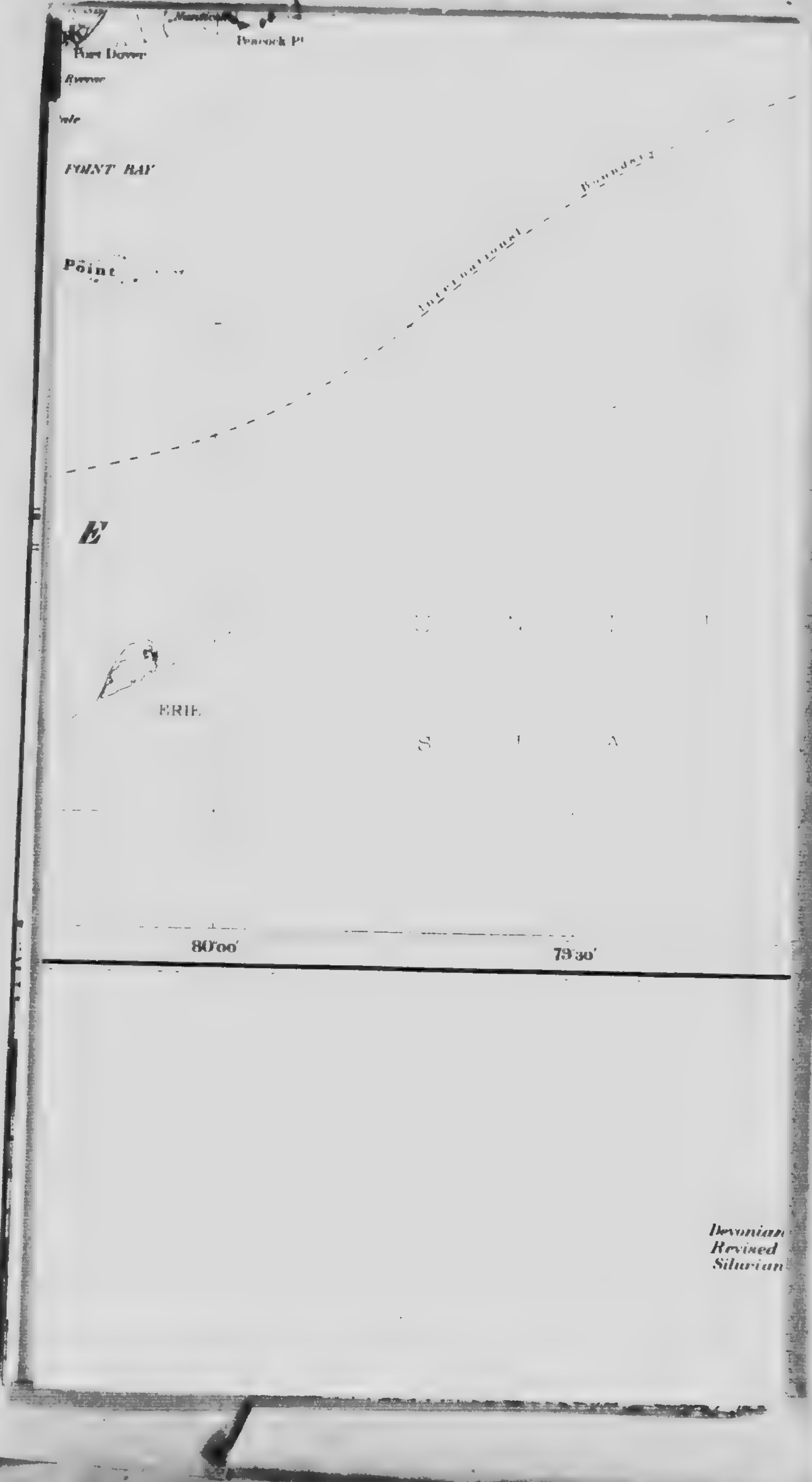
Weber, John, quarry 88
Weller, Stuart 75
Whirlpool sandstone 16, 96
" " fossils 26, 28
" " member 25
" " origin 26
Whiteaves, J. F 3
Whitfieldella cataractensis new species 121
Williamson shale member 49
Wilson, A. W. G 26, 42
Wolverton, Dr 102

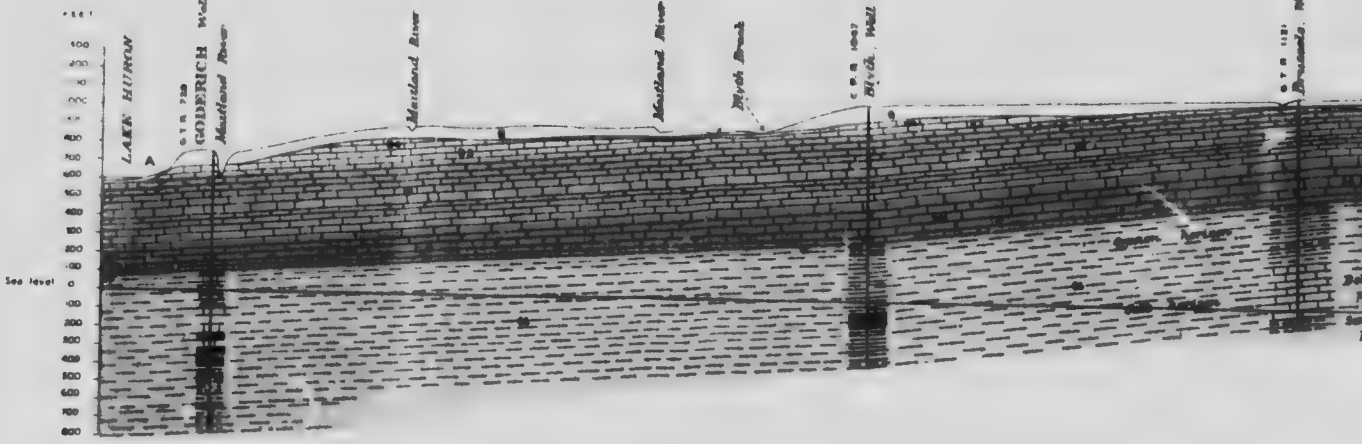
Y.

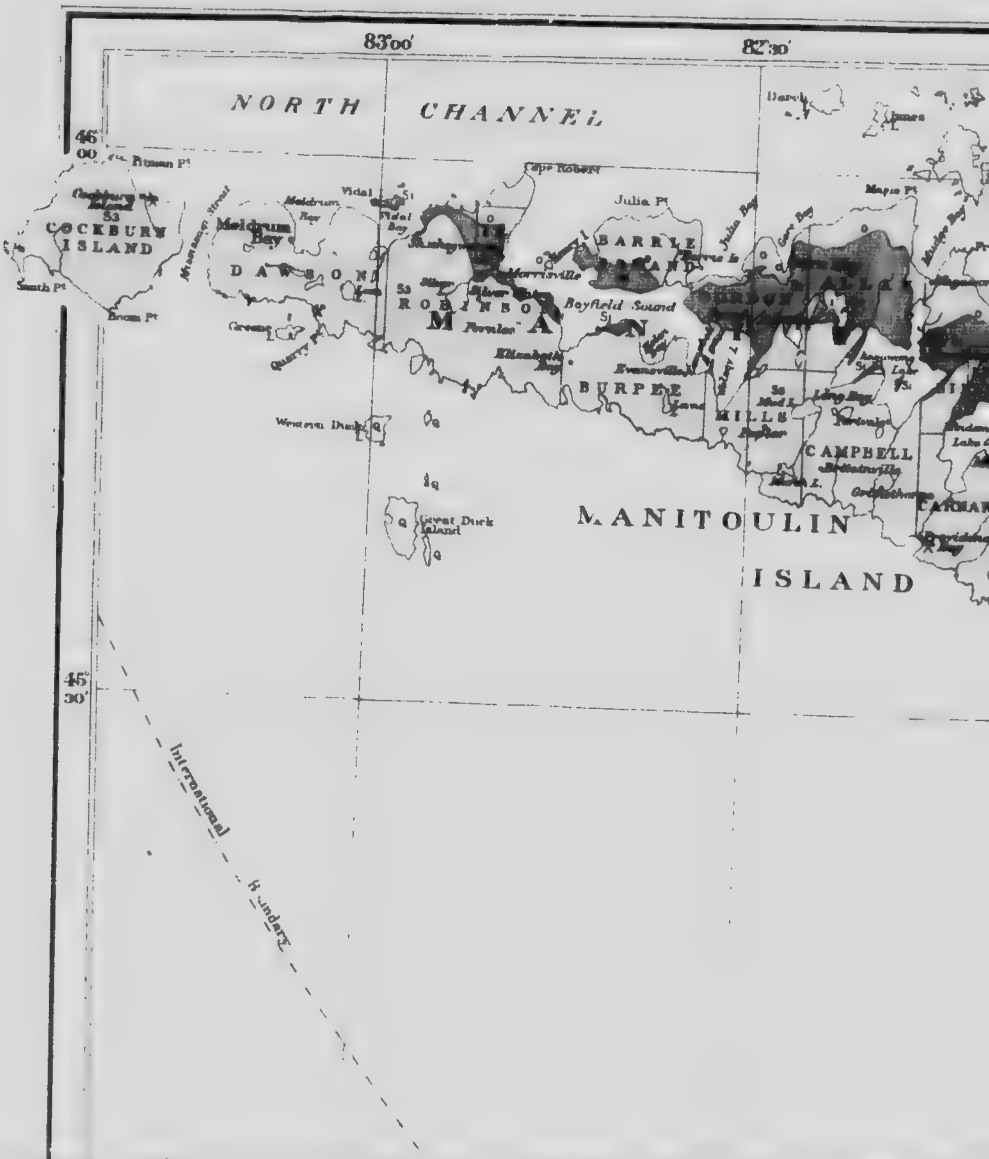
Yeo island 74

Z.

Zinc blende 102


Port Dover
Nanticoke
Peacock Pt
Ryerse
POINT BAY
Point
International Boundary
E
U N I
ERIE
S T A
80°00'
79°30'
Devonian
Revised
Silurian





LEGEND

PLEISTOCENE AND RECENT

Q
Surface deposits
(soils, clay, gravel, etc)

CHEMUNG AND PORTAGE ?

D8
Port Lambton formation
(black and greenish shale with some thin arenaceous (sandy) layers)

GENESSEE ?

D7
Huron shale
(black shale, with large spheroidal concretions near the base

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Hon. Martin Burrell, Minister, R.G. McConnell, Deputy Minister

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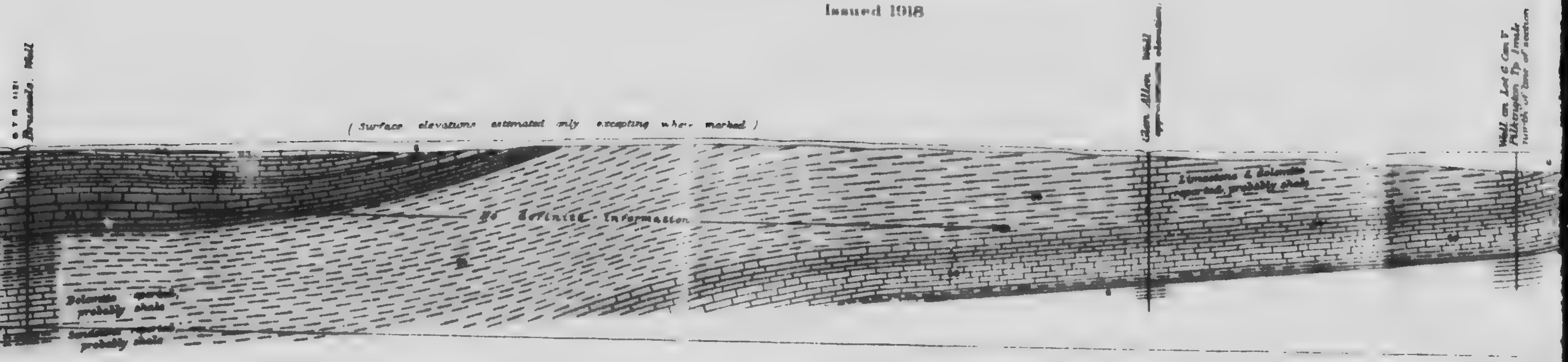
William McInnes, Directing Geologist

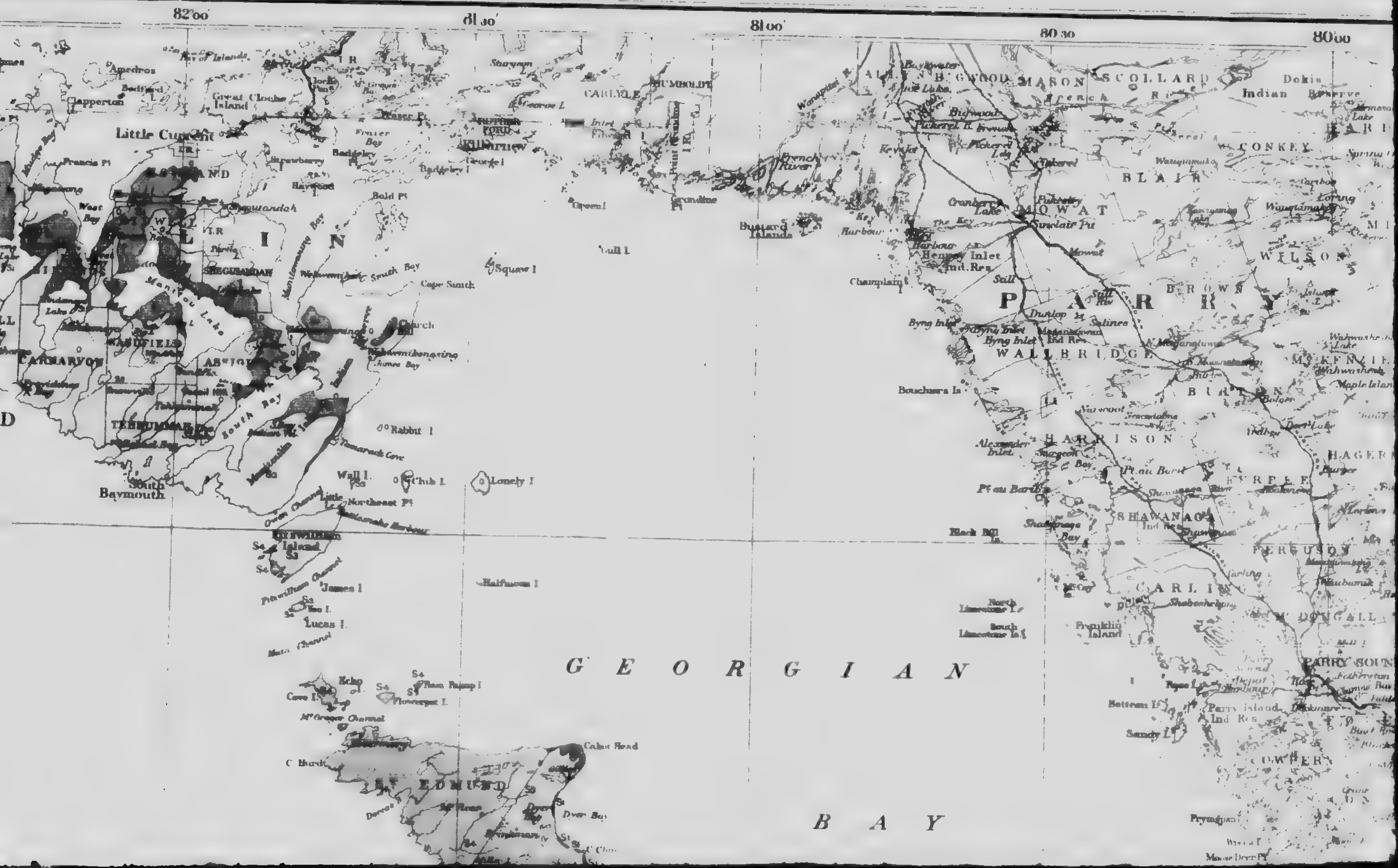
Issued 1918



Brussels Well
(Surface elevations estimated only excepting where marked)
No definite information
Dolomite reported, probably shale
Sandstone reported, probably shale
Glen Allen Well
Limestone & dolomite reported, probably shale
Well on Lot 6 Con V Pilkington Tp ... north of line of section

Structural section along line A-B.

Scale of Miles



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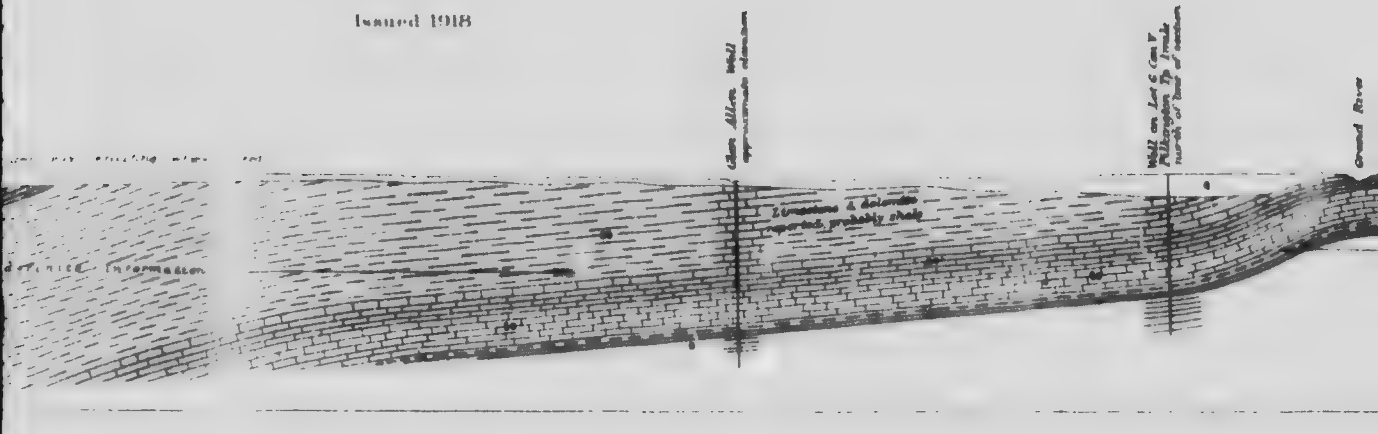
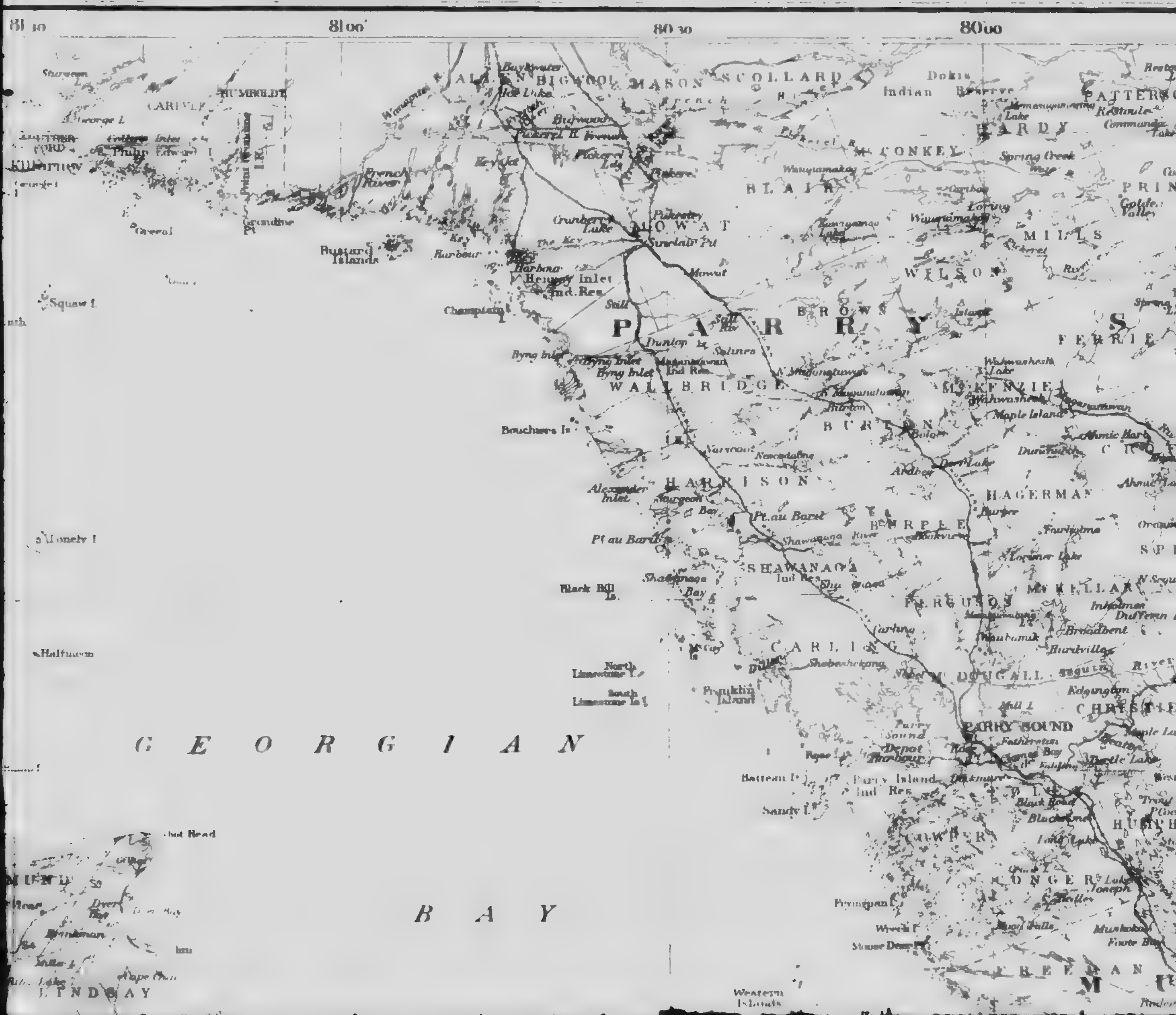
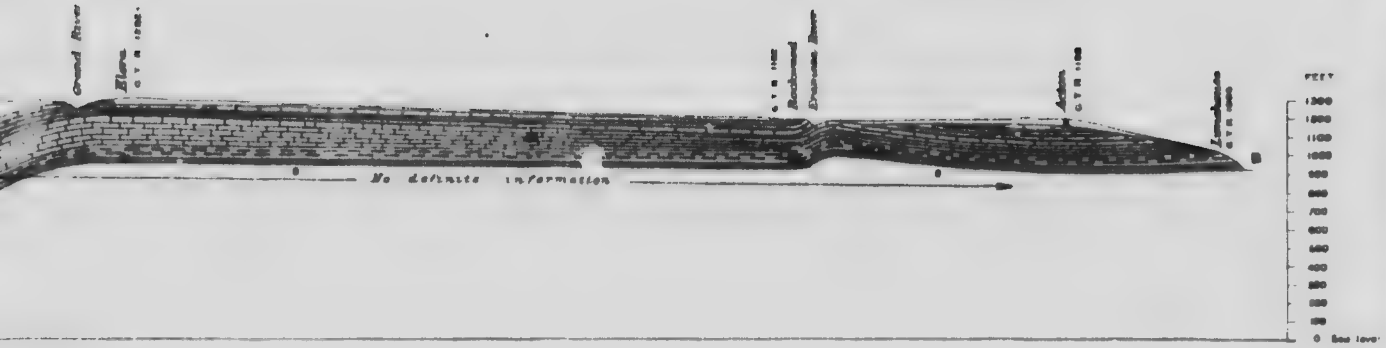


Glen Allen Well approximate elevation
Well on Lot 6 Con V Pilkington Tp
Grand River
Limestone & dolomite reported, probably shale
definite information

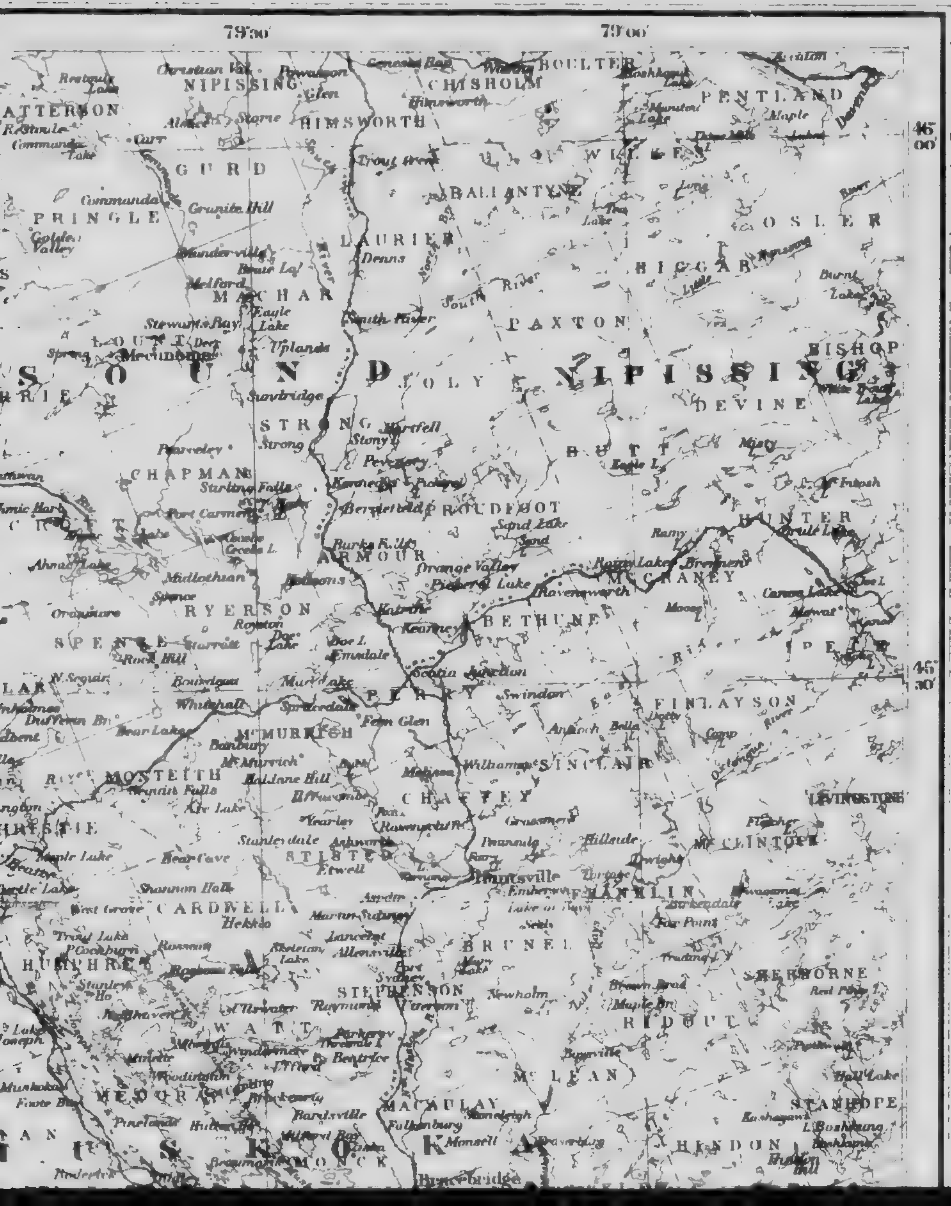
Structural section along line A-B.

Scale of Miles




Grand River
Elora
Rockwood
Credit River
Acton
Limehouse
G.T.R.
No definite information
FEET
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0 Sea level

OUTLINE MAP


79°30'
79°00'
45° 00'
45° 30'
NIPISSING
CHISHOLM
BOULTER
PENTLAND
HIMSWORTH
GURD
PRINGLE
BALLANTYNE
LAURIER
OSLER
BIGGAR
MACHAR
PAXTON
BISHOP
PARRY SOUND
NIPISSING
DEVINE
STRONG
BUTT
CHAPMAN
PROUDFOOT
HUNTER
ARMOUR
McCRANEY
RYERSON
BETHUNE
PERRY
FINLAYSON
McMURRICH
MONTEITH
SINCLAIR
CHAFFEY
LIVINGSTONE
McCLINTOCK
STISTED
CARDWELL
FRANKLIN
BRUNEL
HUMPHREY
STEPHENSON
SHERBORNE
WATT
RIDOUT
McLEAN
MEDORA
MACAULAY
STANHOPE
MUSKOKA
HINDON
MONCK
Huntsville
Bracebridge
Burks Falls
Kearney
Emsdale
Sundridge
South River
Powassan
Trout Creek
Magnetawan
Dorset

black shale with large spheroidal concretions near the base

D VONIAN

HAMILTON

D5 **Ipperwash limestone**
Petrolia shale
Widder beds
Olentangy shale
(gray limestones and soft bluish shales)

D5 **Alpena limestone**
(massive gray limestone)

MARCELLUS

D4 **Delaware limestone**
(blue and brownish limestone, containing some thin interbeds of brown shale)

ONONDAGA

D3 **Onondaga limestone**
(gray to bluish limestone, portions of it very cherty)

ORISKANY

D2 **Oriskany sandstone**
(coarse white to yellowish sandstone)

DETROIT RIVER SERIES

■ **Lucas dolomite**
Amherstburg dolomite
Anderdon limestone
Flat Rock dolomite ?
(buff and brown dolomites, and gray limestone)

SILURIAN

CAYUGAN GROUP

■ **Akron dolomite**
Bertie waterlime
(Including 'Lower Monroe' of Detroit River region)
(gray dolomite) (dark gray waterlime)

SALINA

S5 **Camillus shale**
(gray, green and red shales, containing gray dolomite, salt and gypsum interbedded)

GUELPH

S4 **Guelph dolomite**
(light gray, buff and brown dolomites)

NIAGARA

S3 **Lockport dolomite**
(light gray and white dolomites, and arenaceous (sandy) bituminous dolomite at the top)

CLINTON

■ **Rochester shale**
Clinton dolomite and shale
(gray shale) (gray dolomite and shale)

MEDINA-CATARACT

S1 **Thorold sandstone**
Grimsby sandstone
Cabot Head shale
Manitoulin dolomite
Whirlpool sandstone
(gray and red sandstones and shales and gray or buff dolomite, arenaceous (sandy), in Niagara Peninsula)

ORDOVICIAN

QUEENSTON RICHMOND ETC.

O **Queenston shale and Richmond formation**
(red arenaceous (sandy) shale, gray shale and limestone.)

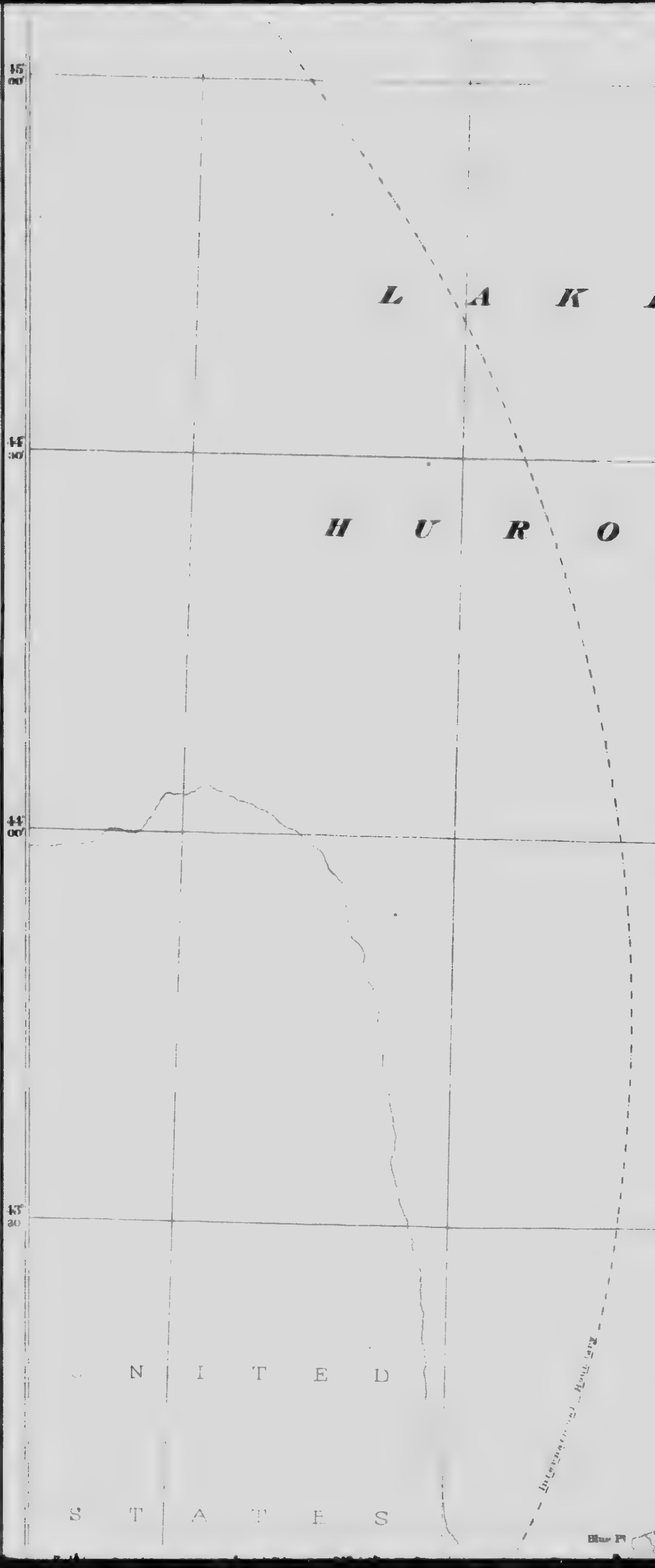
Symbols

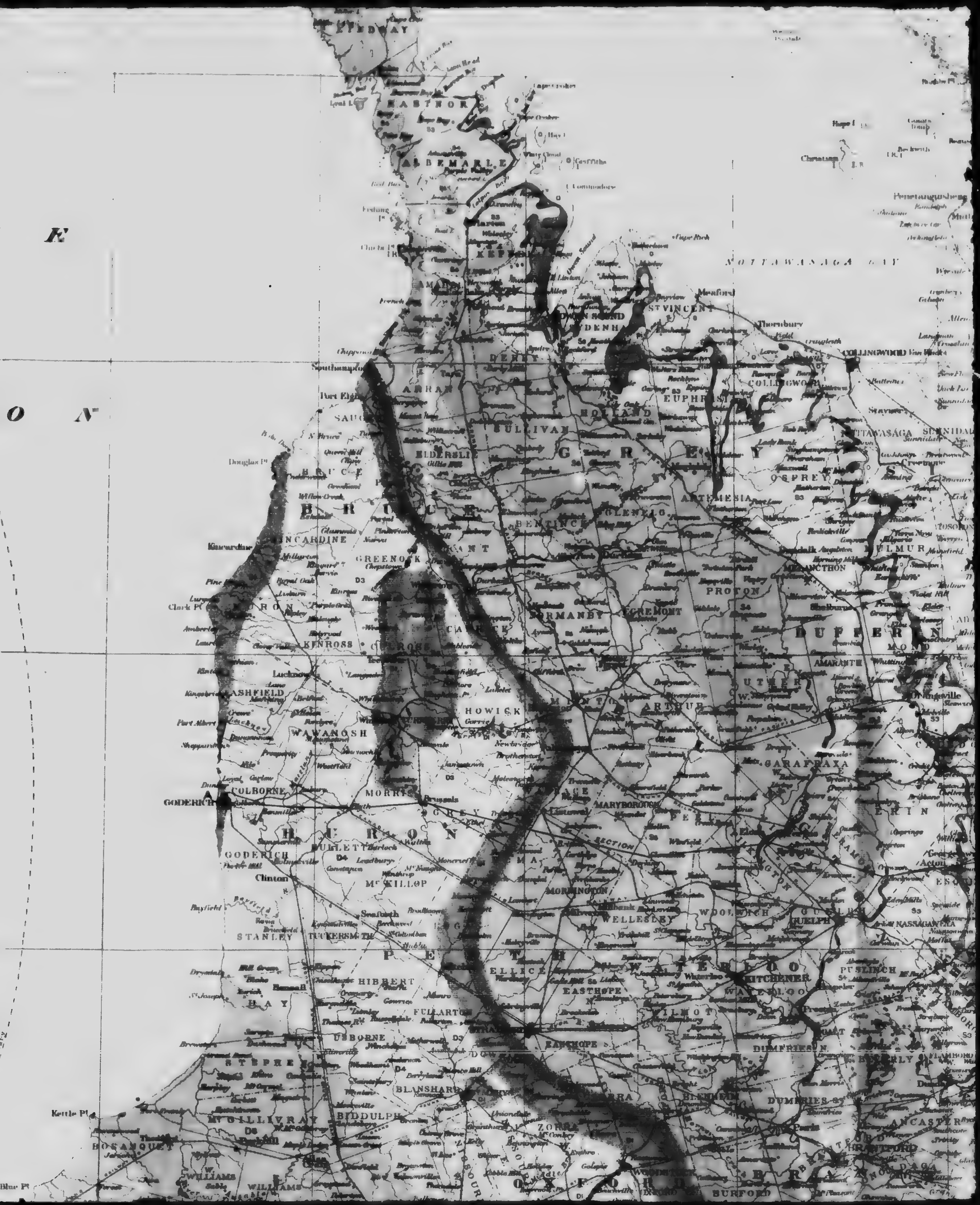
● **Rock outcrops**
(On the Manitoulin Island, Bruce Peninsula and along the Niagara escarpment outcrops of rock are very common, but have not been specifically mapped. Elsewhere the recorded outcrops are shown.)

⚒ **Quarries**

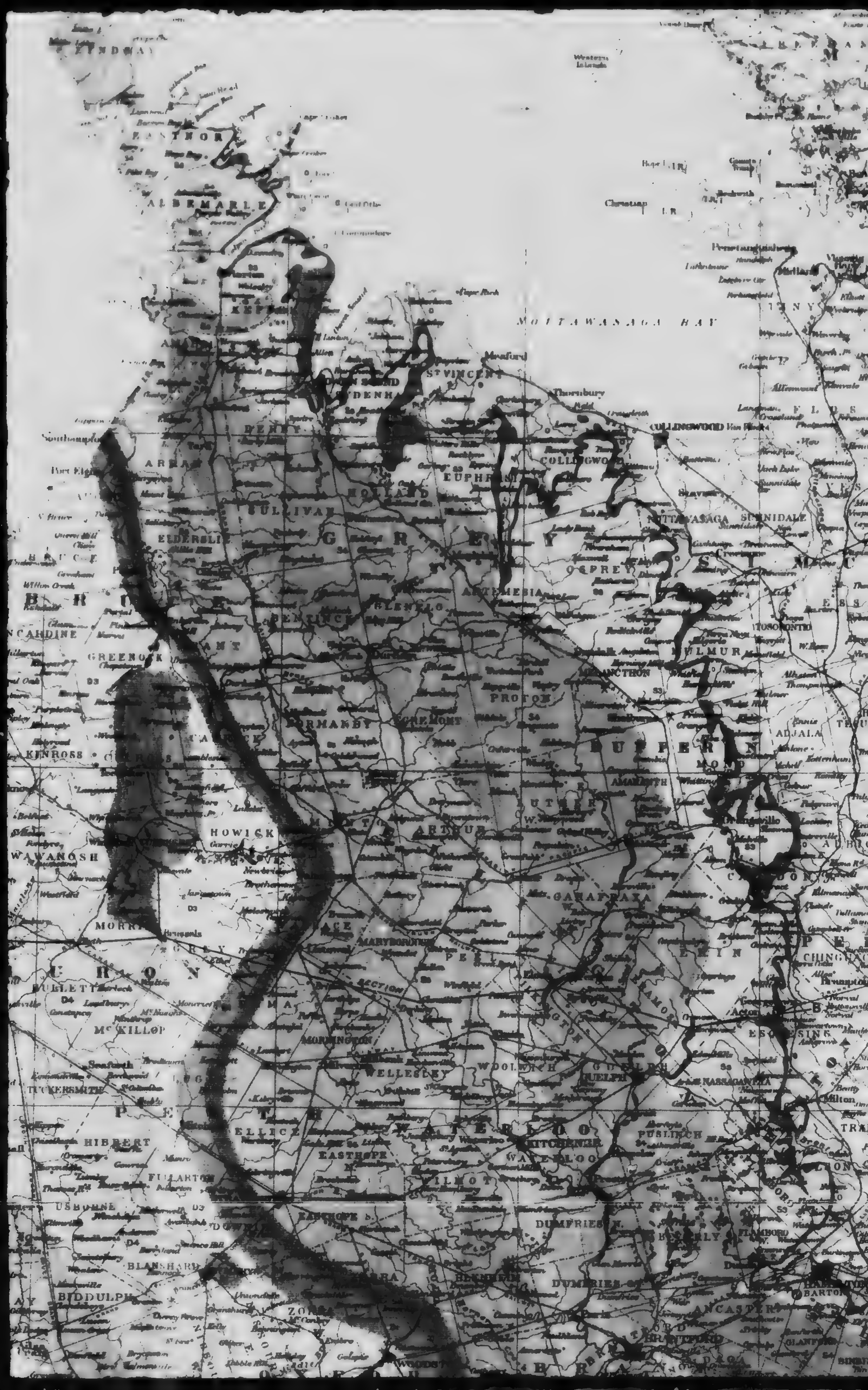
▦ **Limestone or dolomite**

▤ **Shale**





EASTNOR
ALBEMARLE
AMABEL
KEPPEL
NOTTAWASAGA BAY
ST VINCENT
OWEN SOUND
SYDENHAM
Meaford
Thornbury
COLLINGWOOD
COLLINGWOOD
Penetanguishene
Southampton
Port Elgin
SAUGEEN
ARRAN
DERBY
SULLIVAN
HOLLAND
EUPHRASIA
NOTTAWASAGA
ELDERSLIE
G R E Y
OSPREY
ARTEMESIA
B R U C E
BENTINCK
GLENELG
KINCARDINE
Kincardine
GREENOCK
BRANT
MELANCTHON
MULMUR
PROTON
NORMANBY
EGREMONT
KINROSS
CULROSS
CARRICK
D U F F E R I N
AMARANTH
MONO
ASHFIELD
Lucknow
HOWICK
MINTO
ARTHUR
LUTHER
Orangeville
WAWANOSH
GARAFRAXA
MORRIS
COLBORNE
GODERICH
MARYBOROUGH
PEEL
ERIN
H U R O N
HULLETT
GODERICH
Clinton
McKILLOP
MORNINGTON
WELLESLEY
WOOLWICH
GUELPH
Acton
Bayfield
Seaforth
STANLEY
TUCKERSMITH
P E R T H
ELLICE
W A T E R L O O
KITCHENER
Waterloo
PUSLINCH
HIBBERT
EASTHOPE N.
HAY
FULLARTON
WILMOT
USBORNE
EASTHOPE
DUMFRIES N.
STEPHEN
BLANSHARD
BLENHEIM
DUMFRIES S.
BEVERLY
McGILLIVRAY
BIDDULPH
ZORRA
ANCASTER
BOSANQUET
WILLIAMS
BRANTFORD
O X F O R D
BURFORD
Kettle Pt
Blue Pt
Goderich
E
O N



LINDSAY
EASTNOR
ALBEMARLE
Western Islands
Christian I.
Penetanguishene
NOTTAWASAGA BAY
Meaford
ST VINCENT
SYDENHAM
Thornbury
COLLINGWOOD
Collingwood
Southampton
Port Elgin
ARRAN
DERBY
EUPHRASIA
HOLLAND
SULLIVAN
ELDERSLIE
G R E Y
NOTTAWASAGA
SUNNIDALE
OSPREY
ARTEMESIA
GLENELG
BENTINCK
B R U C E
KINCARDINE
GREENOCK
BRANT
MELANCTHON
MULMUR
TOSORONTIO
PROTON
NORMANBY
EGREMONT
ADJALA
KINROSS
CULROSS
DUFFERIN
AMARANTH
MONO
HOWICK
MINTO
ARTHUR
Orangeville
WAWANOSH
GARAFRAXA
MORRIS
MARYBOROUGH
PEEL
ERIN
GREY
H U R O N
CHINGUACOUSY
MULLETT
McKILLOP
MORNINGTON
ESQUESING
Acton
Seaforth
TUCKERSMITH
WELLESLEY
WOOLWICH
GUELPH
NASSAGAWEYA
Milton
ELLICE
WATERLOO
KITCHENER
PUSLINCH
HIBBERT
EASTHOPE
WILMOT
FULLARTON
USBORNE
DUMFRIES N.
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BIDDULPH
ZORRA
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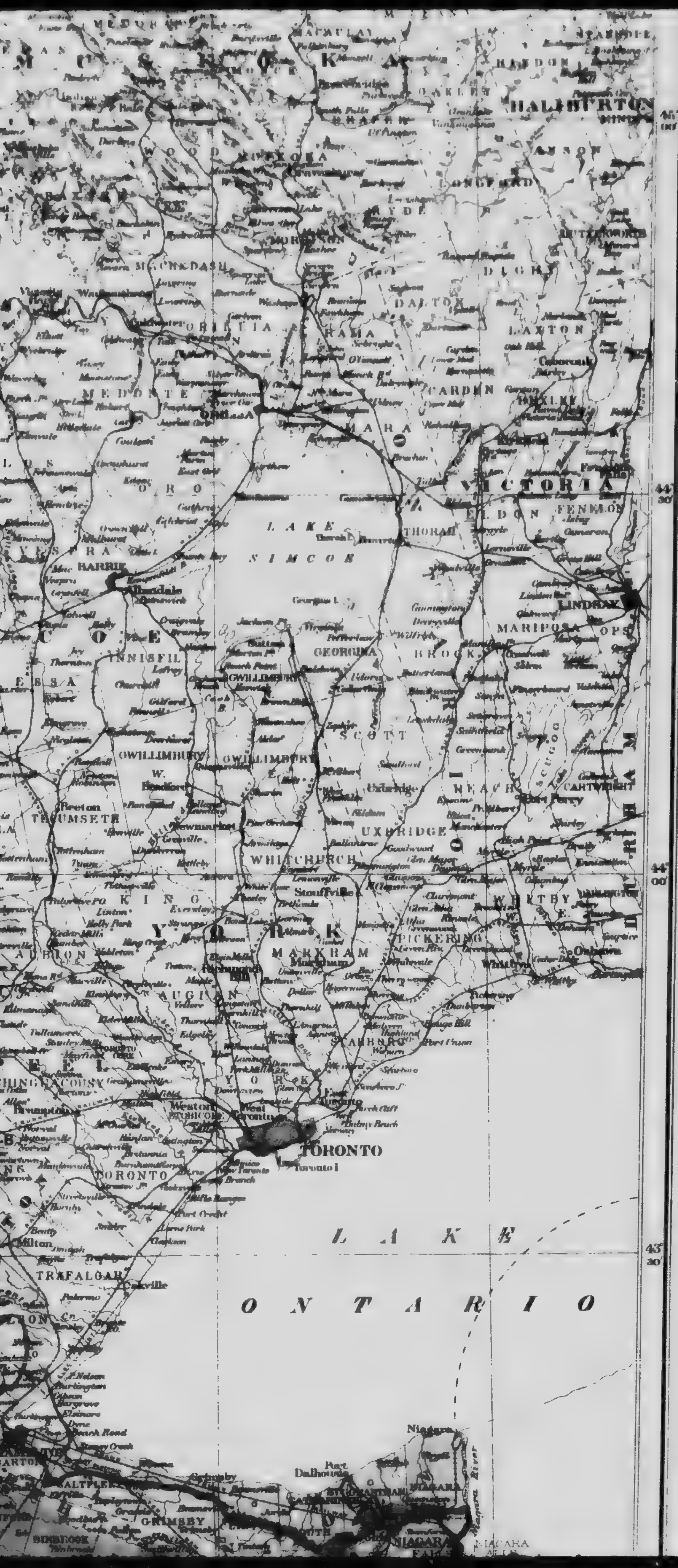
BRANTFORD
BARTON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OAKLEY
HALIBURTON
MINDEN
WOOD
MUSKOKA
ANSON
LONGFORD
RYDE
MORRISON
BUTTERWORTH
MCHEDASH
DIGBY
DALTON
ORILLIA
RAMA
LAXTON
MEDONTE
CARDEN
Orillia
BEXLEY
MARA
ORO
VICTORIA
ELDON
FENELON
LAKE SIMCOE
THORAH
VESPRA
BARRIE
Allandale
LINDSAY
MARIPOSA
OPS
SIMCOE
INNISFIL
GEORGINA
BROCK
ESSA
GWILLIMBURY
SCOTT
W. GWILLIMBURY
E. GWILLIMBURY
Bradford
REACH
CARTWRIGHT
Beeton
TECUMSETH
Uxbridge
UXBRIDGE
Port Perry
Newmarket
WHITCHURCH
DURHAM
ONTARIO
KING
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E.
PICKERING
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Oshawa
VAUGHAN
Richmond Hill
Markham
SCARBORO
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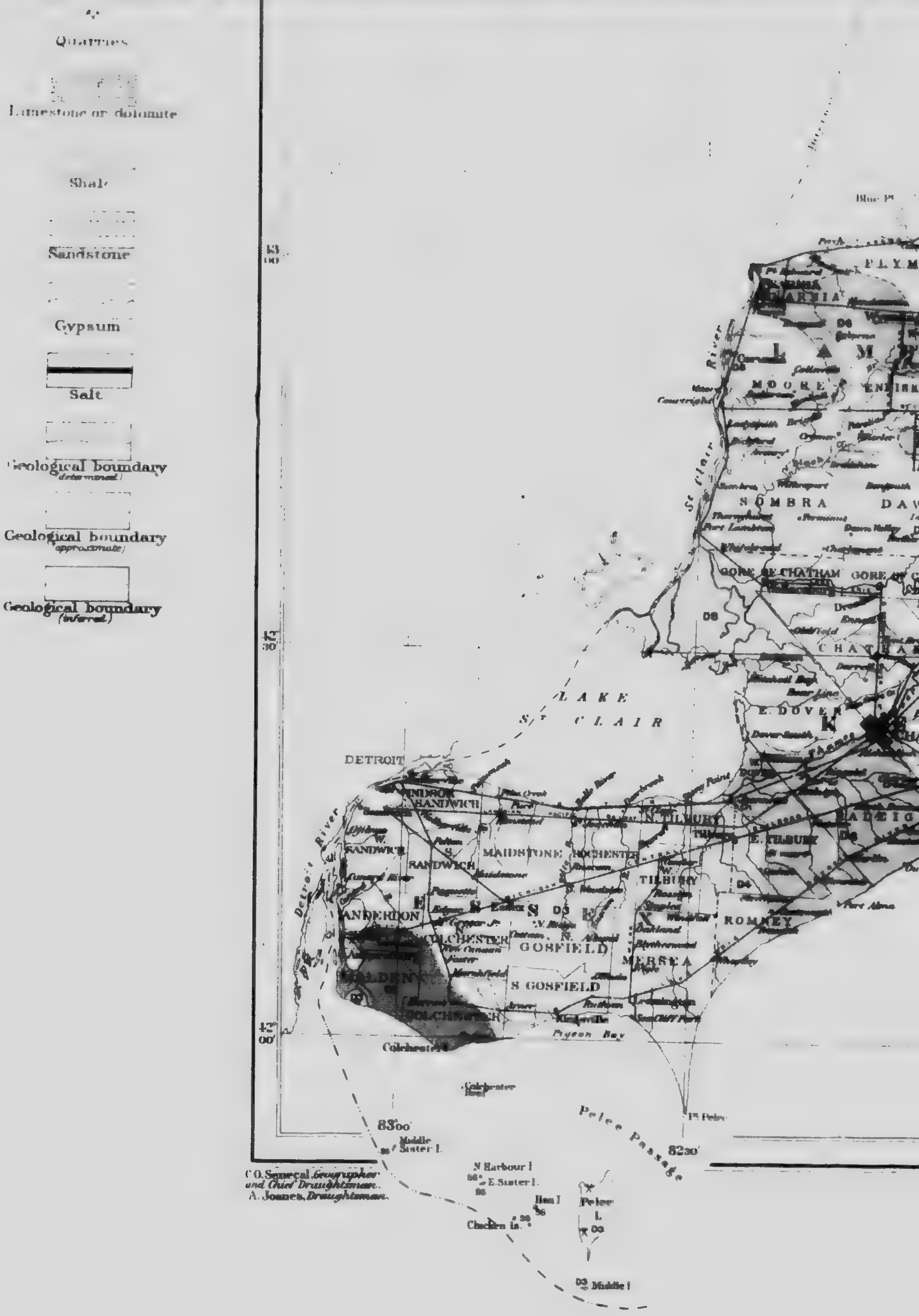
YORK
Weston
ETOBICOKE
West Toronto
Brampton
TORONTO
TORONTO
Milton
TRAFALGAR
Oakville
LAKE ONTARIO
Burlington
Niagara
Dalhousie
Grimsby
St. Catharines
NIAGARA
GRIMSBY
Niagara River
NIAGARA FALLS
SALTFLEET
BINBROOK
45° 00'
44° 30'
44° 00'
43° 30'



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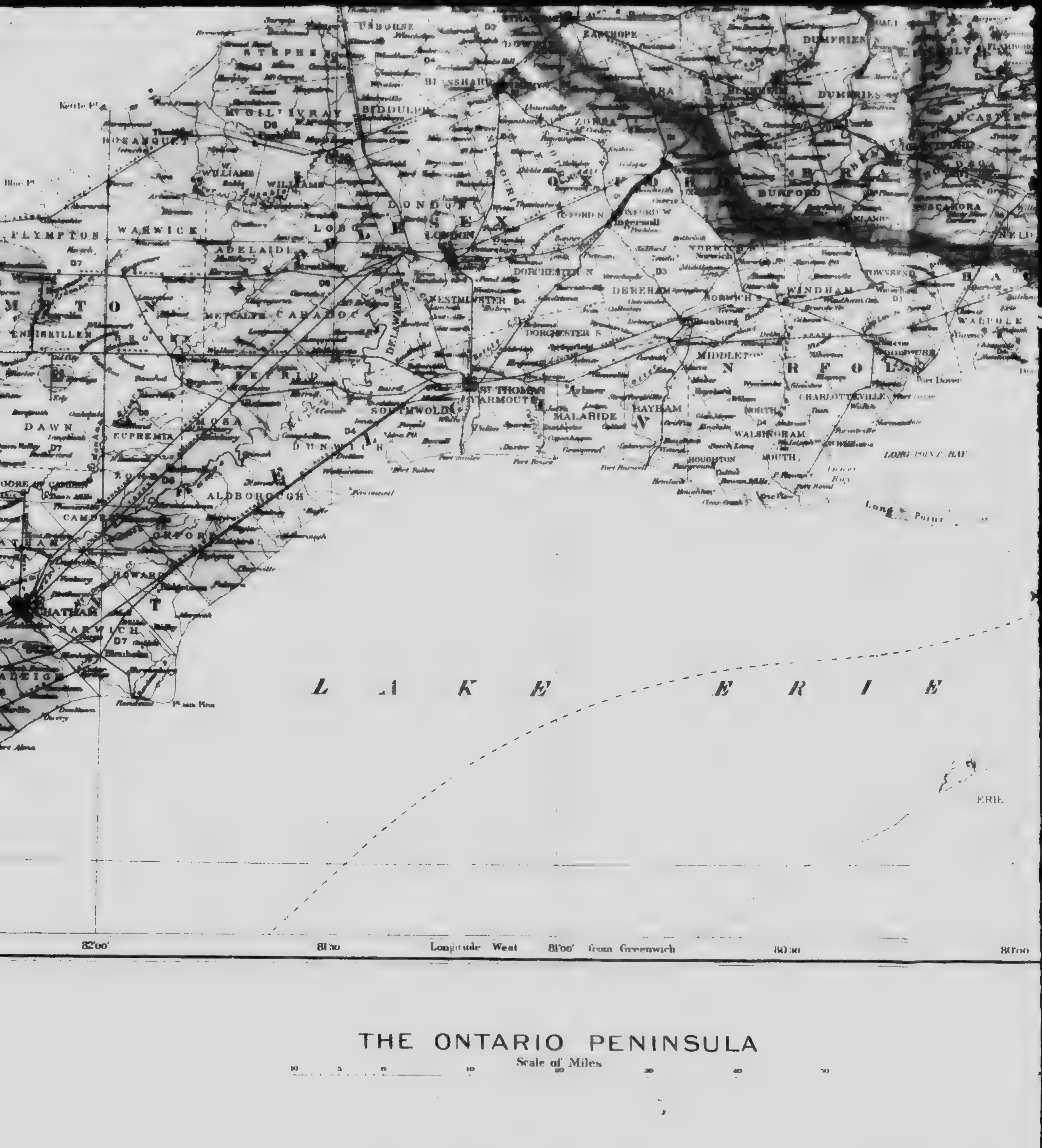
To accompany Memoir by M.Y. Williams



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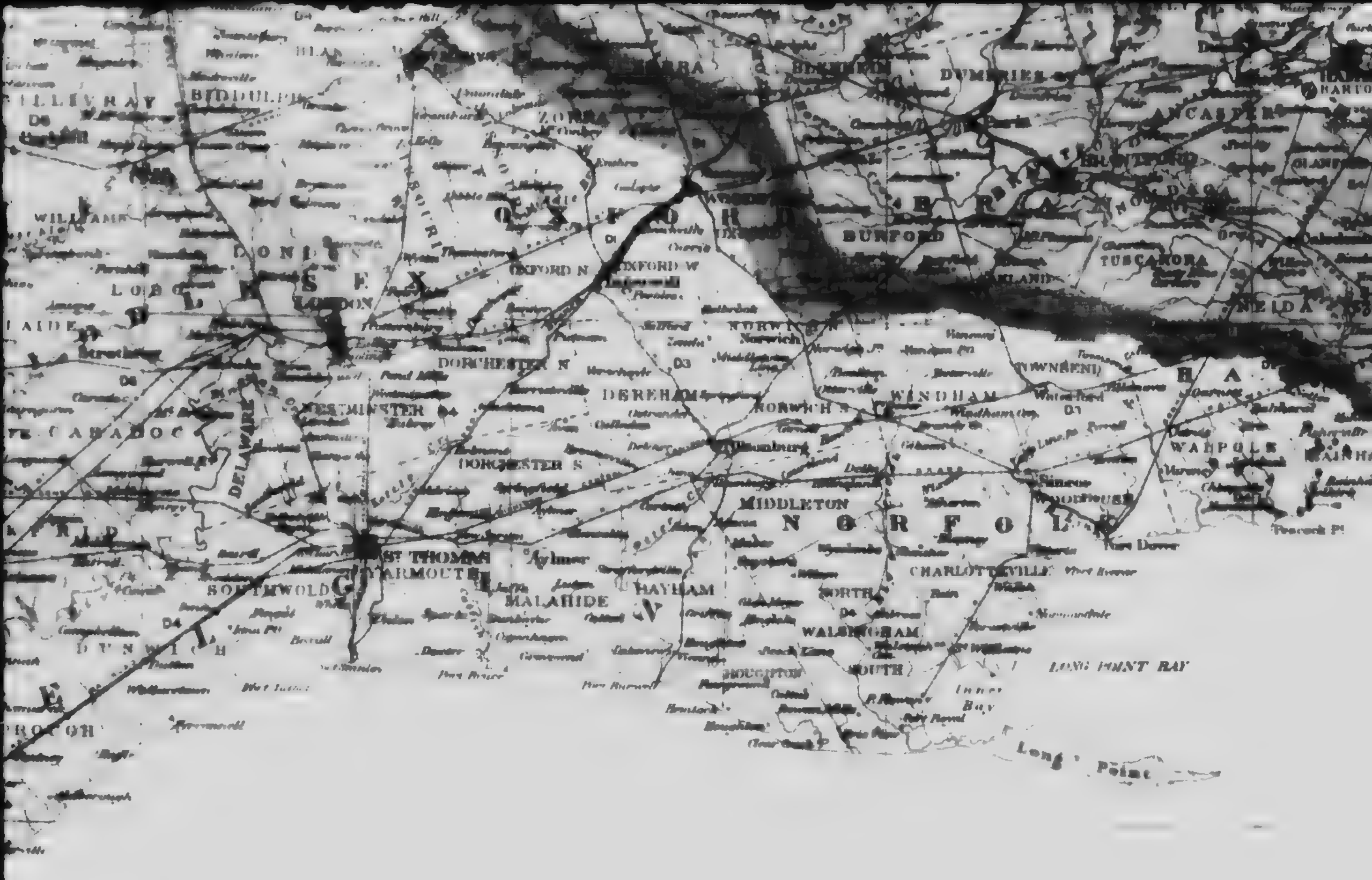
Scale of Miles

10 5 0 10 20 30 40 50



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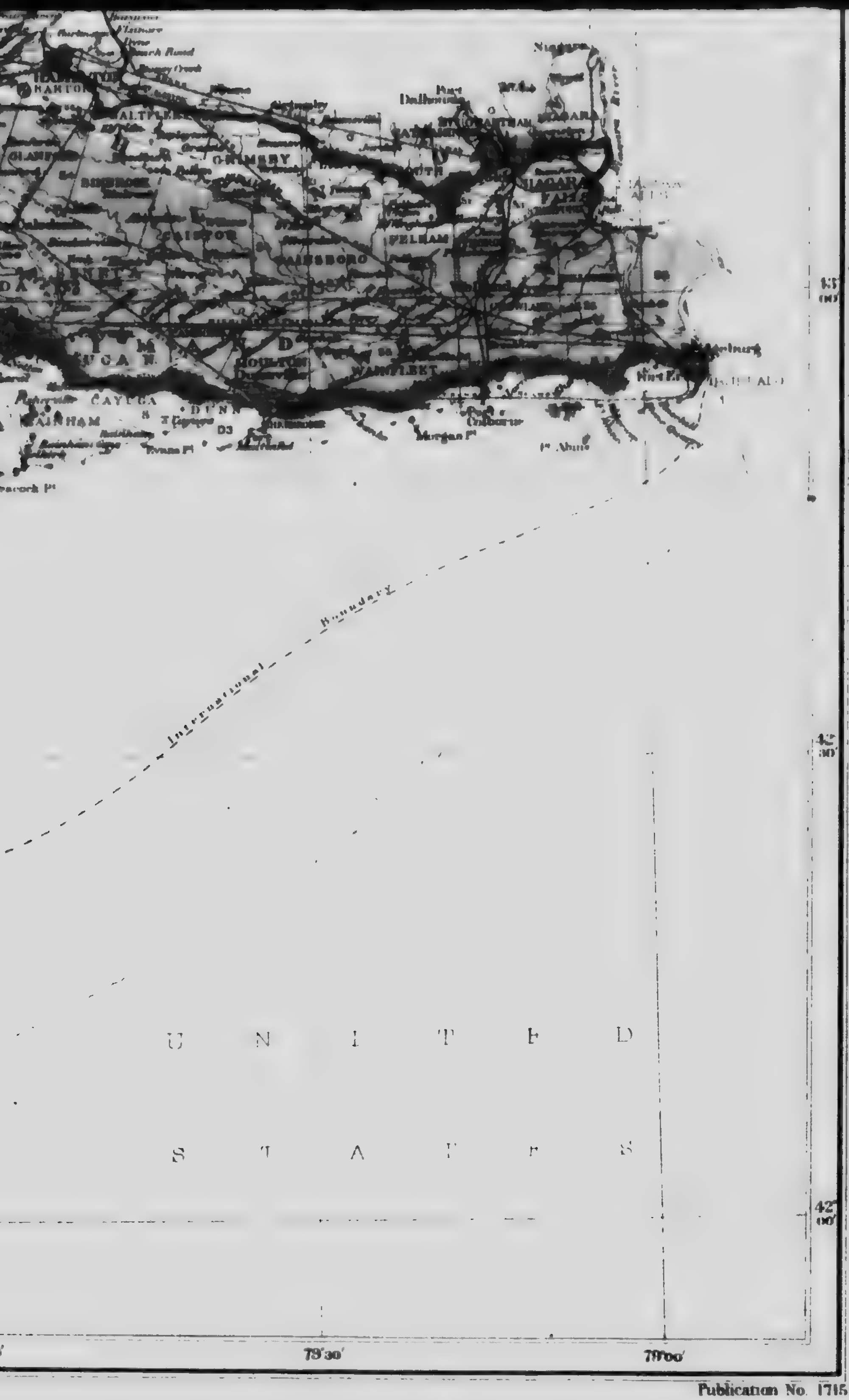

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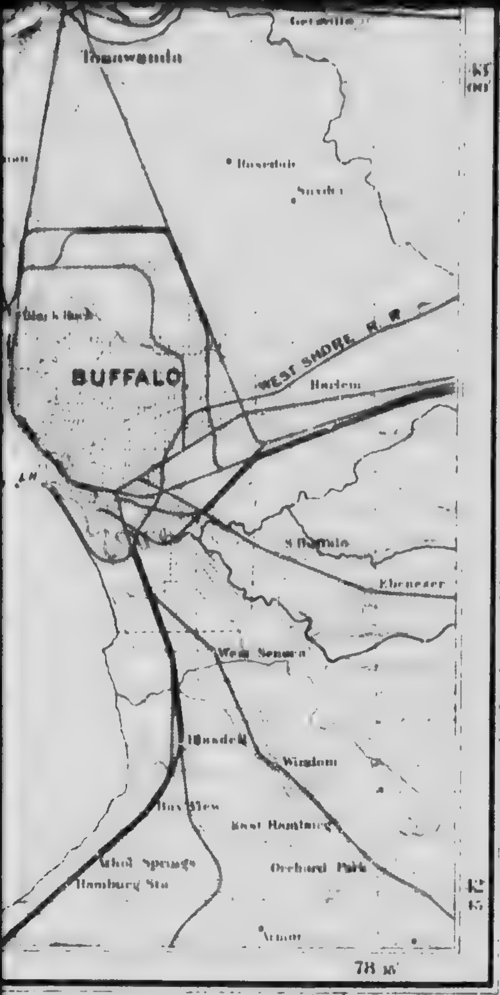

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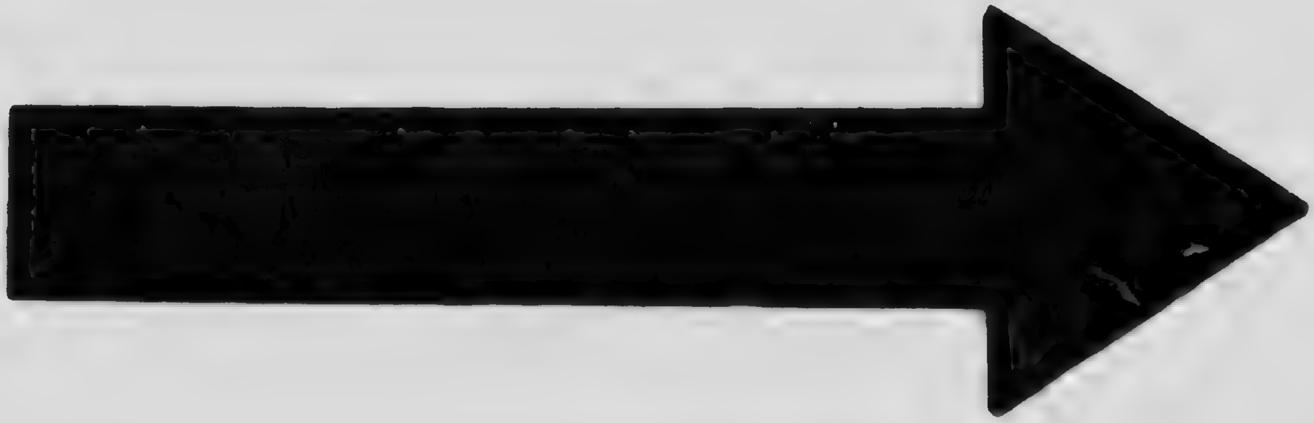

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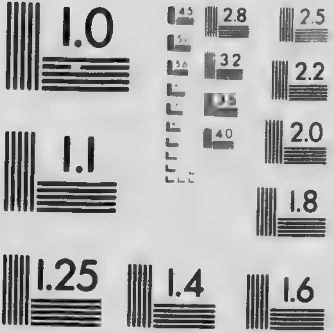

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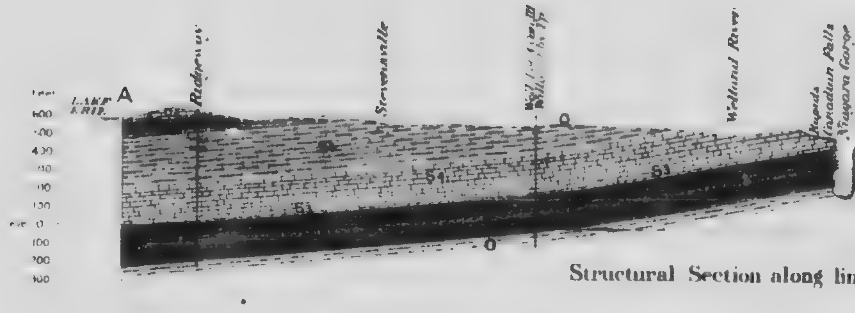
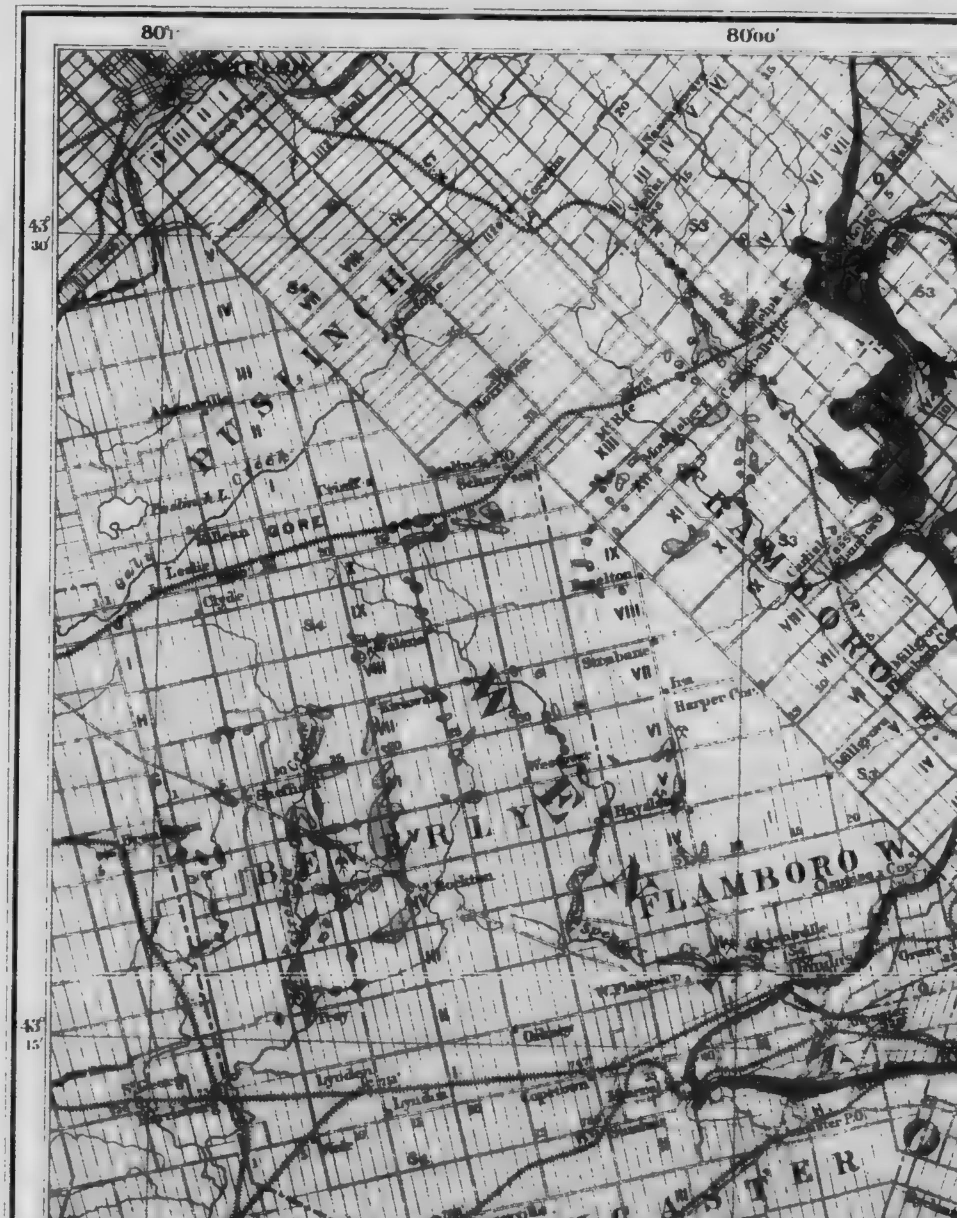


Structural Section along lin

LEGEND

PLEISTOCENE AND RECENT		Q	Surface deposits (soils, clay, gravel, etc.)
DEVONIAN	MARCELLUS	D4	Delaware limestone (blue and brownish limestone, containing some thin interbeds of brown shale)
	ONONDAGA	D3	Onondaga limestone (gray to bluish limestone, portions of it very cherty)
	ORISKANY	D2	Oriskany sandstone (coarse white to yellowish sandstone)
SILURIAN	CAYUGAN GROUP	S6	Akron dolomite Bertie waterlime (gray dolomite, dark gray waterlime)
	SALINA	S5	Camillus shale (gray and green shales, containing gray dolomite, and gypsum interbeaded)
	GUELPH	S4	Guelph dolomite (light gray, buff and brown dolomites)
	NIAGARA	S3	Lockport dolomite (light gray and white dolomites and arenaceous (sandy) bituminous dolomite at the top)



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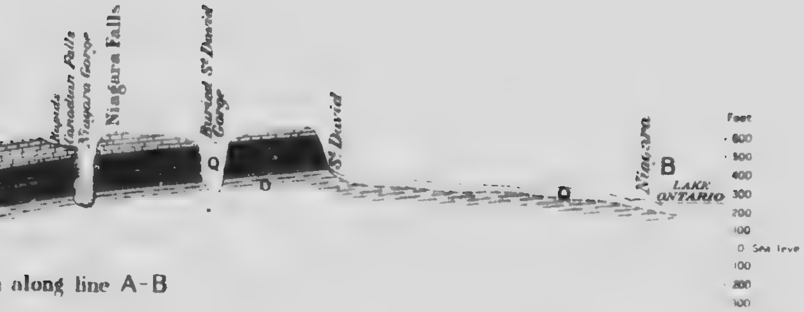
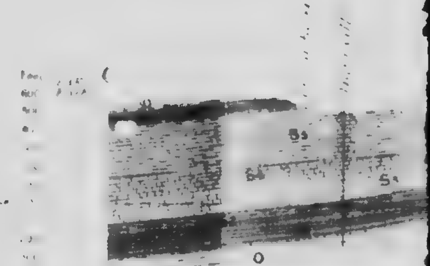
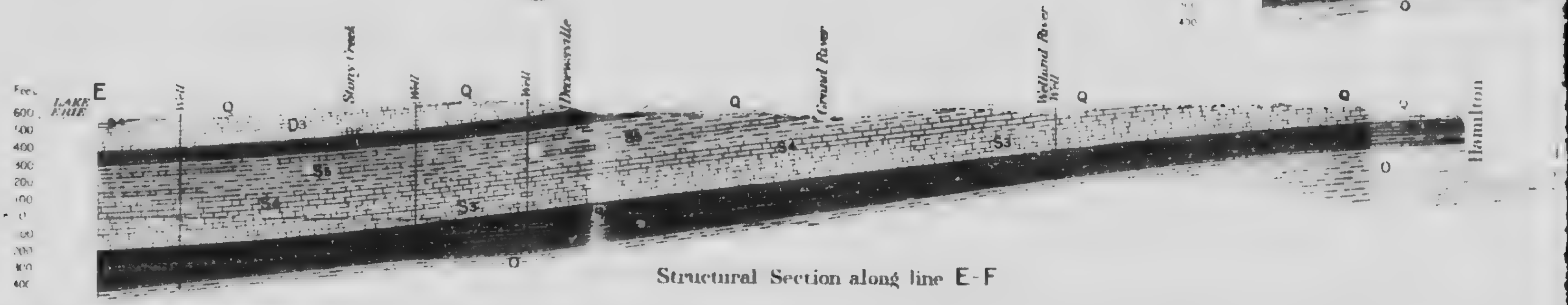
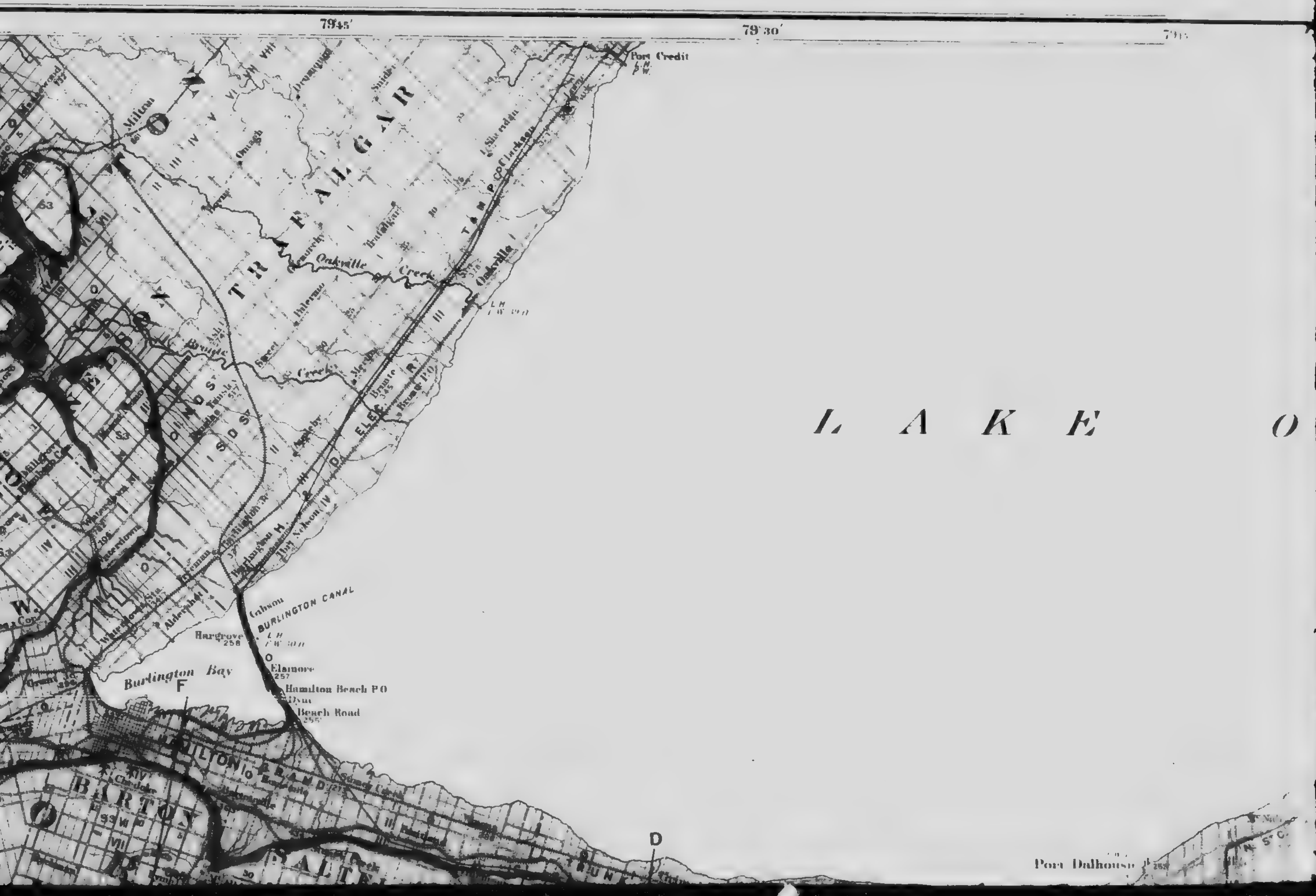


along line A-B





Structural Section along line E-F



Canada
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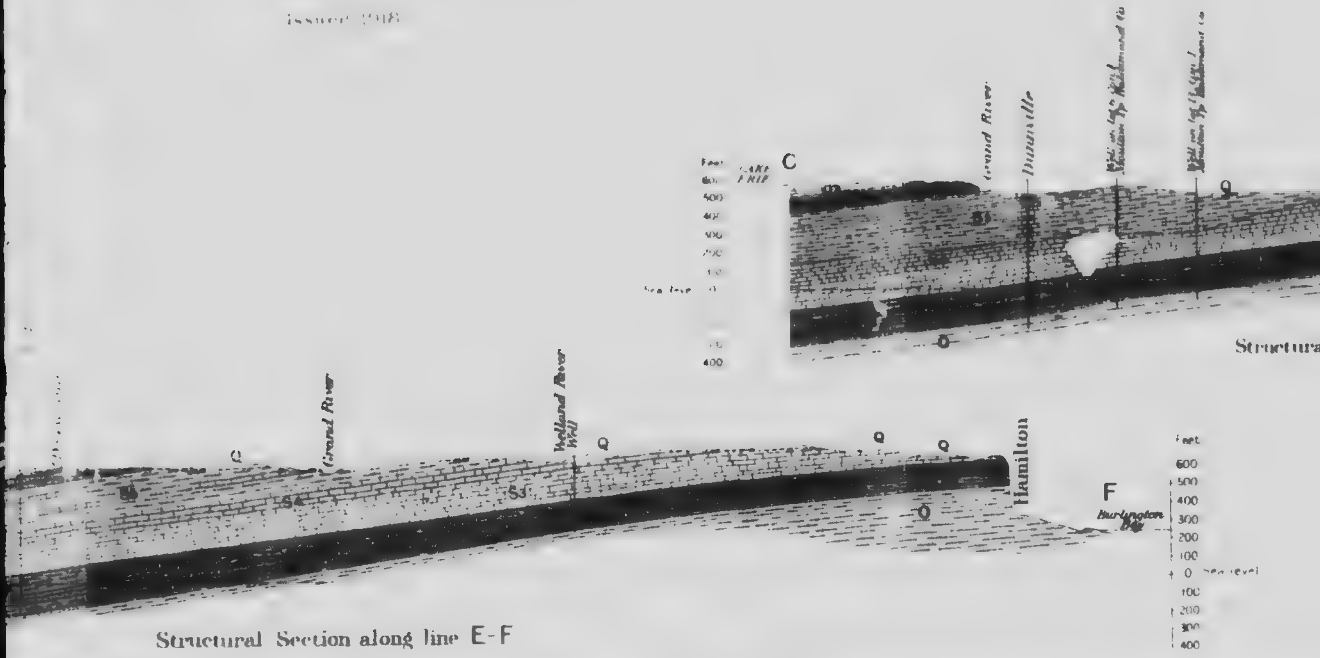
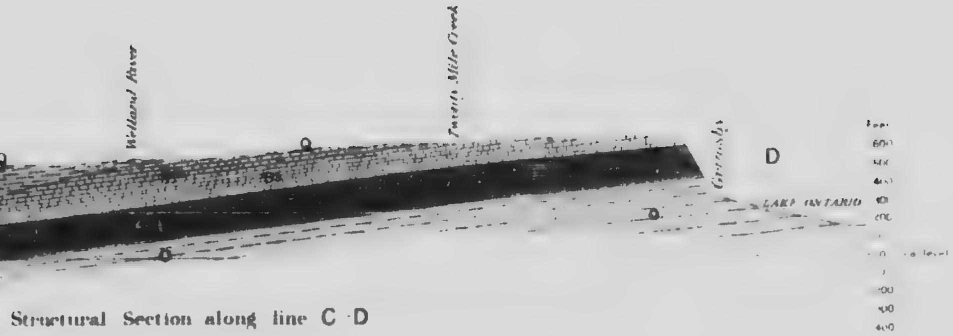
GEOLOGICAL SURVEY

Issued 1918

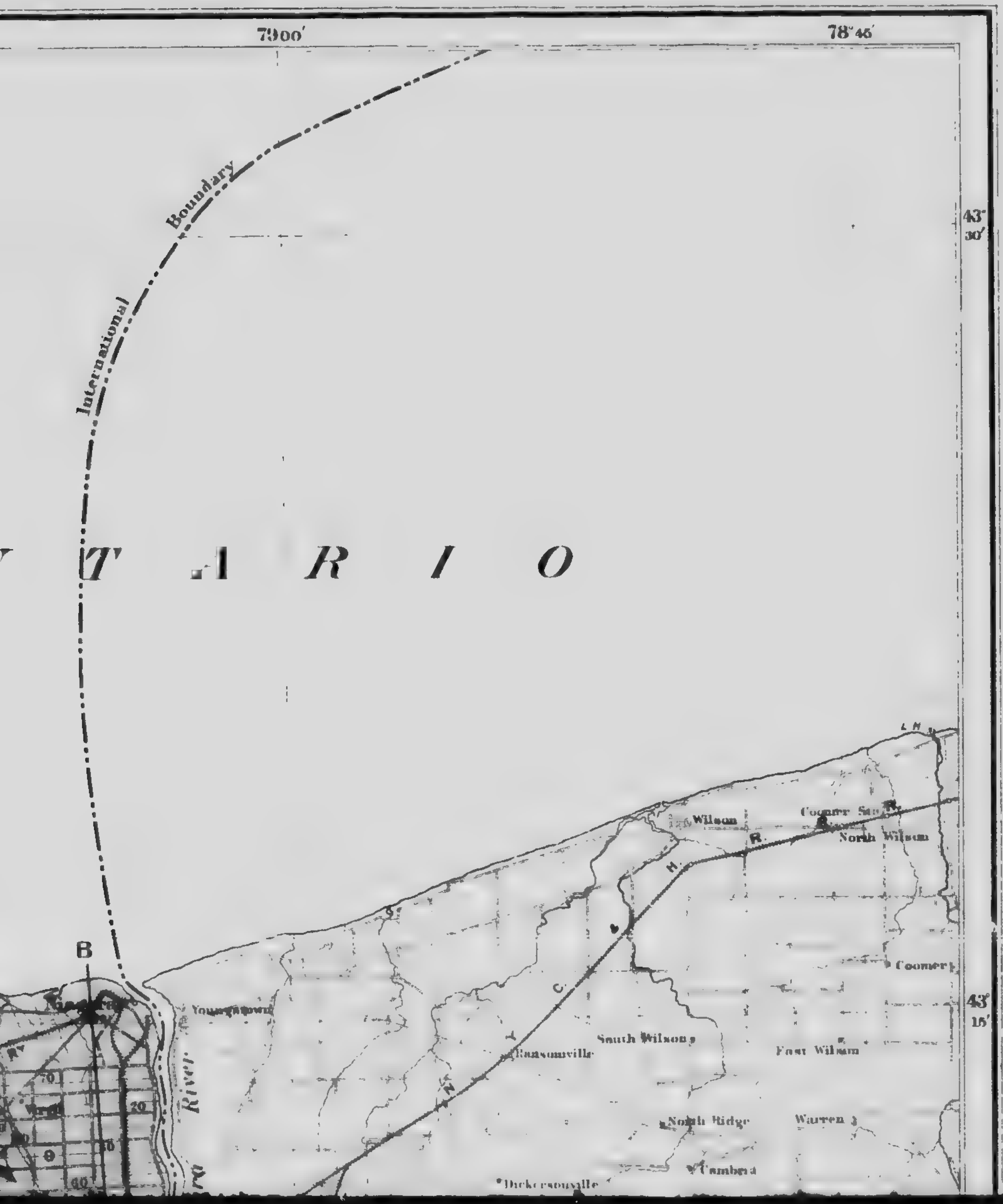


Structura

Structural Section along line E-F



Structural Section along line C-D



SILURIA

ORDOVICIAN

dolomite
(light gray, buff and brown dolomites)

NIAGARA

S3

Lockport dolomite
(light gray and white dolomites and arenaceous (sandy), bituminous dolomite at the top)

CLINTON

Rochester shale
Clinton dolomite and shale
(gray shale) (gray dolomite and shale)

MEDINA-CATARACT

Thorold sandstone
Grimsby sandstone
Cabot Head shale
Manitoulin dolomite
Whirlpool sandstone
(gray and red sandstones and shales, and arenaceous (sandy) dolomite)

QUEENSTON

O

Queenston shale
(red arenaceous (sandy) shale)

Symbols

Rock outcrops
(along the Niagara escarpment, outcrops of rock are very common, but have not been specifically mapped. Elsewhere the recorded outcrops are shown.)

⚒ **Quarries**

Limestone or dolomite

Shale

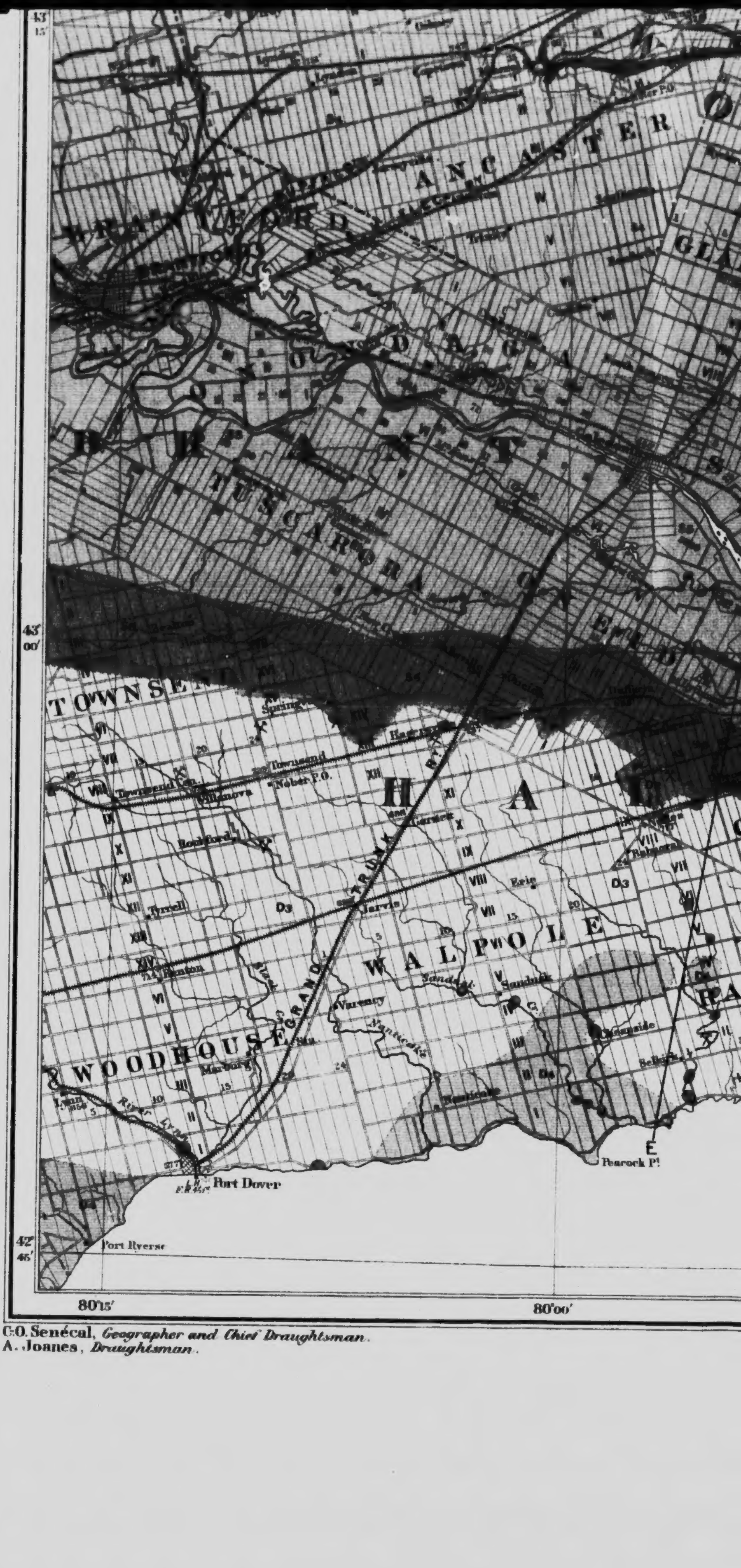
Sandstone

Gypsum

Geological boundary
(determined)

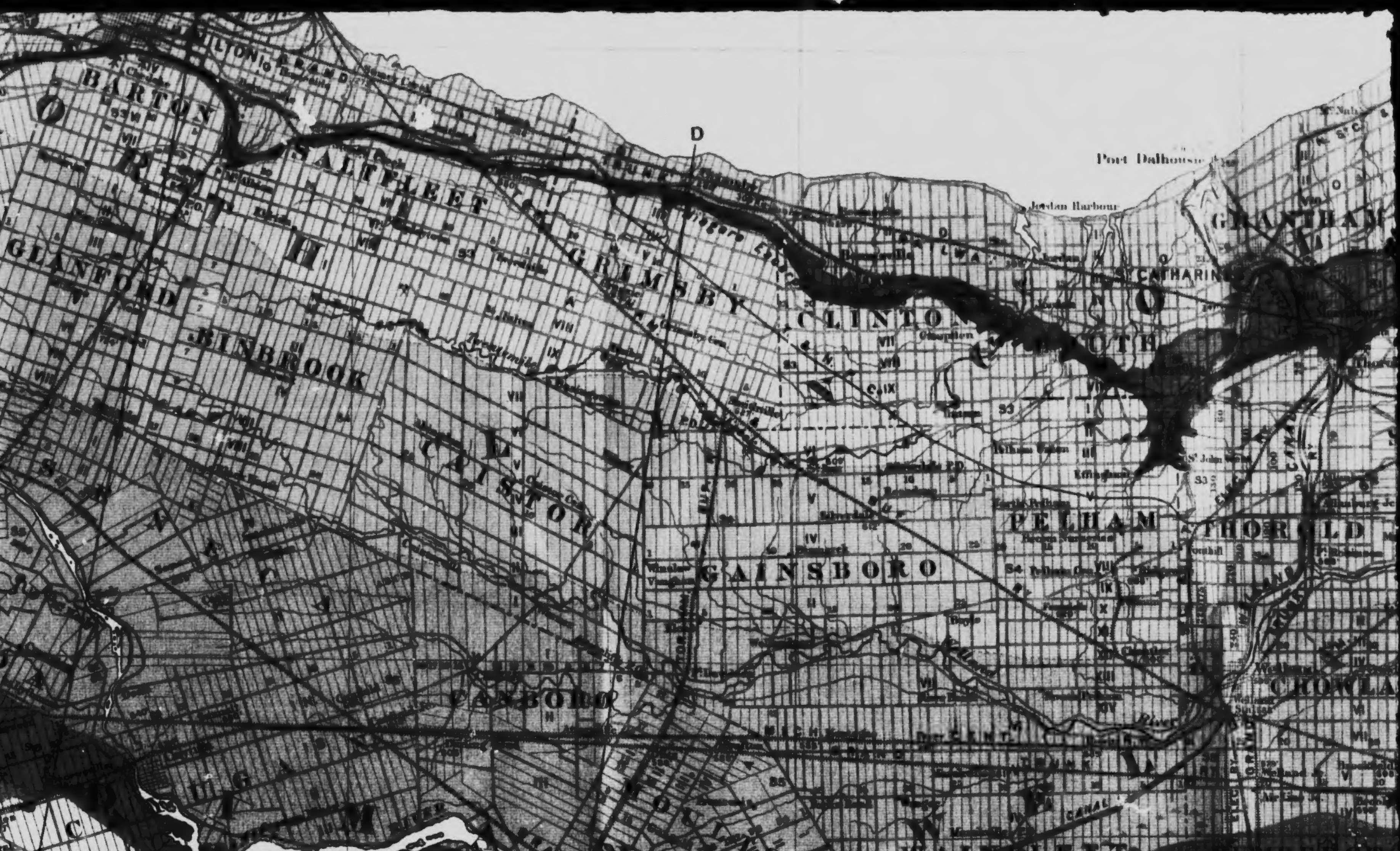
Geological boundary
(approximate)

Geological boundary
(inferred)



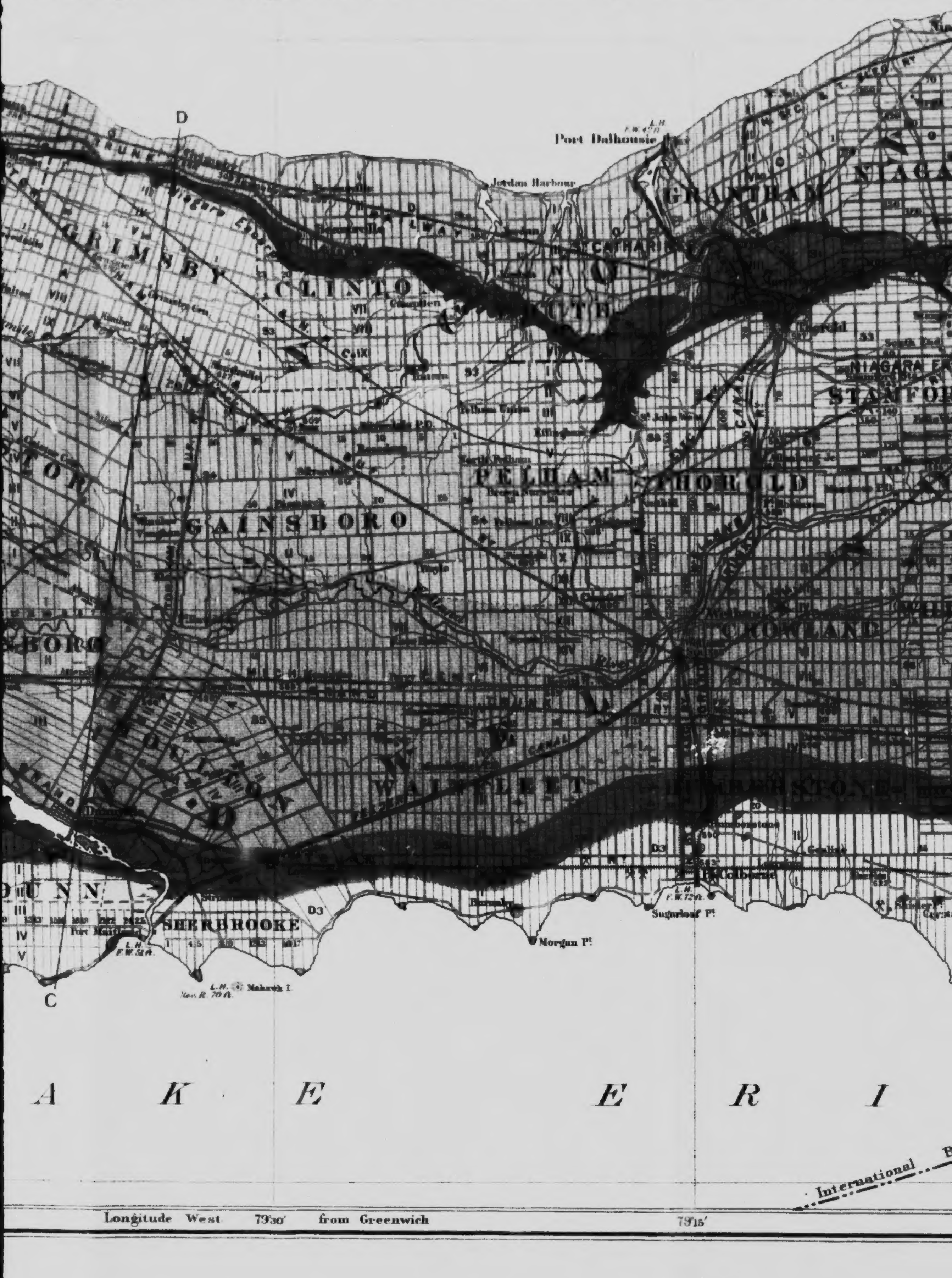
C.O. Senécal, *Geographer and Chief Draughtsman.*
A. Joanes, *Draughtsman.*

To accompany Memoir by M.Y. Williams

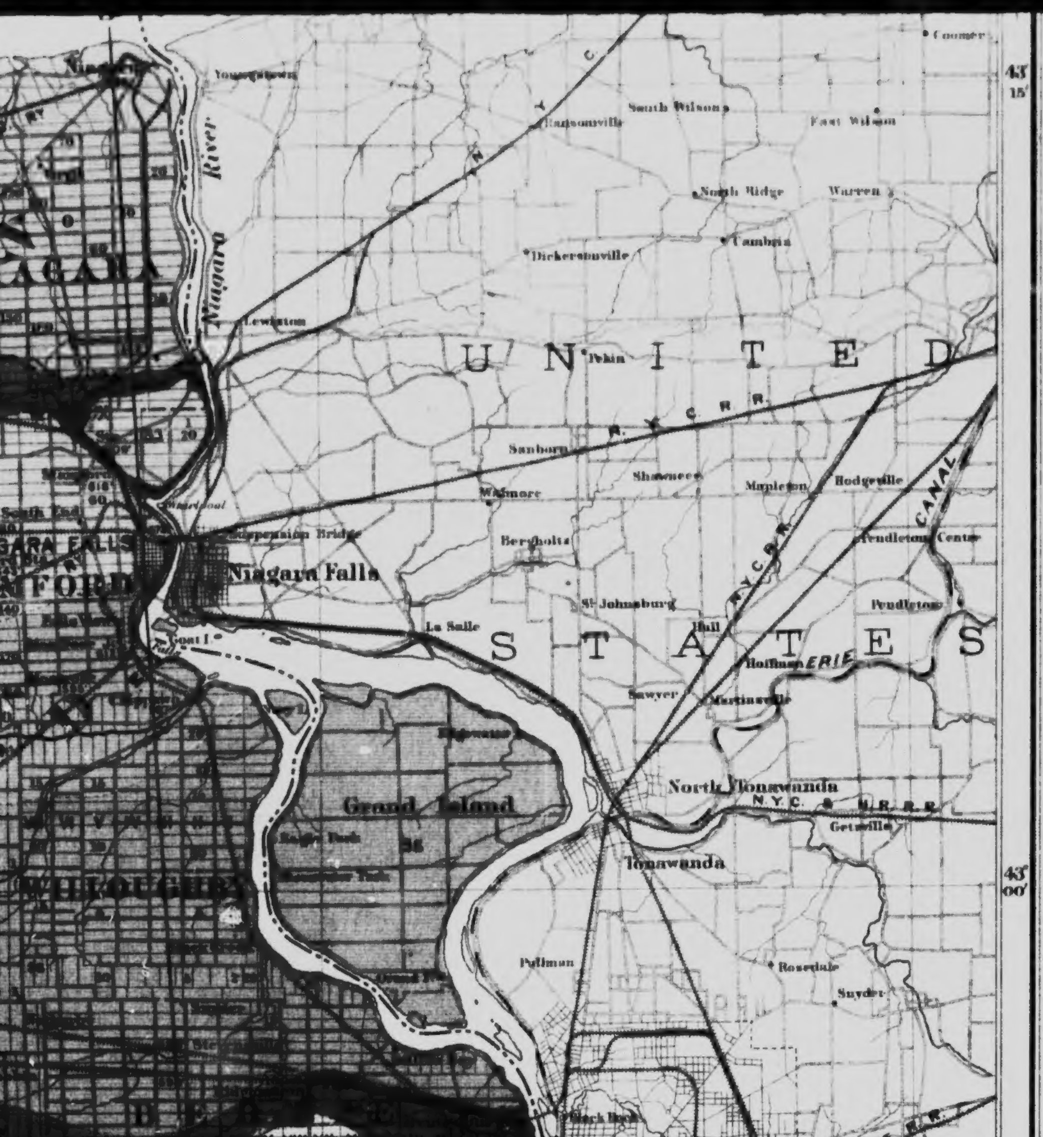


THE NIAGARA PENINSULA, ONTARIO

Scale of miles



E NIAGARA PENINSULA, ONTARIO



Publication No. 1714

Base map from engraved plates of the Department of the Interior

Devonian geology by C.R. Stauffer *1910-1912*
Silurian geology by M.Y. Williams *1912-1916*